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THE ENGINEER

JANUARY 13, 1961

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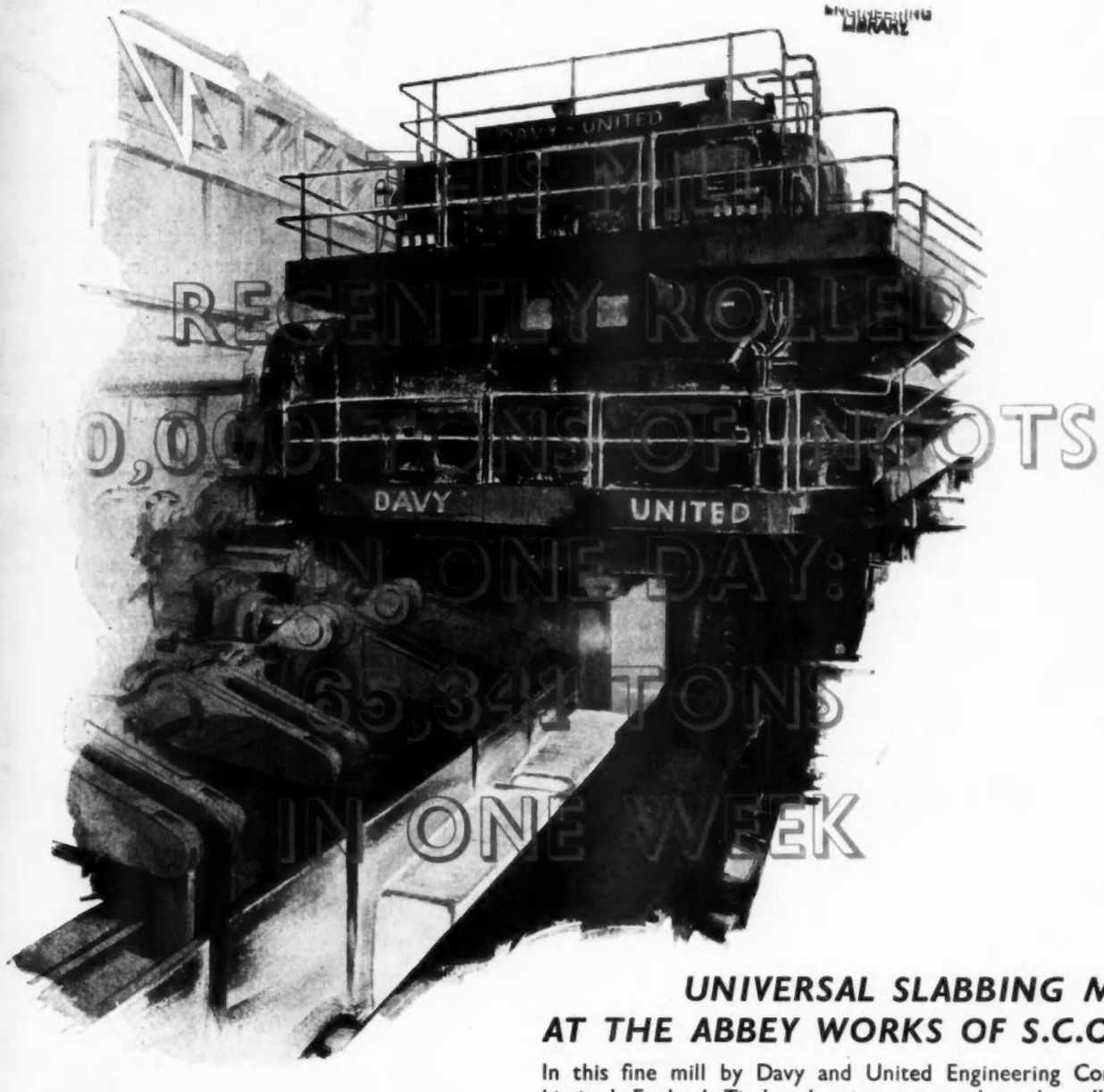

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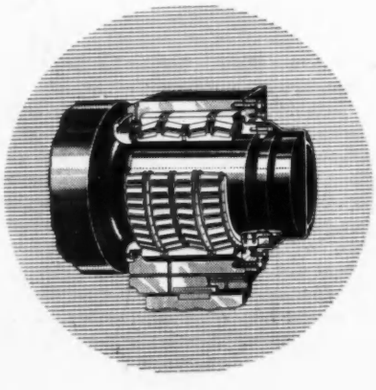

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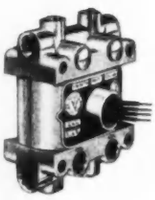

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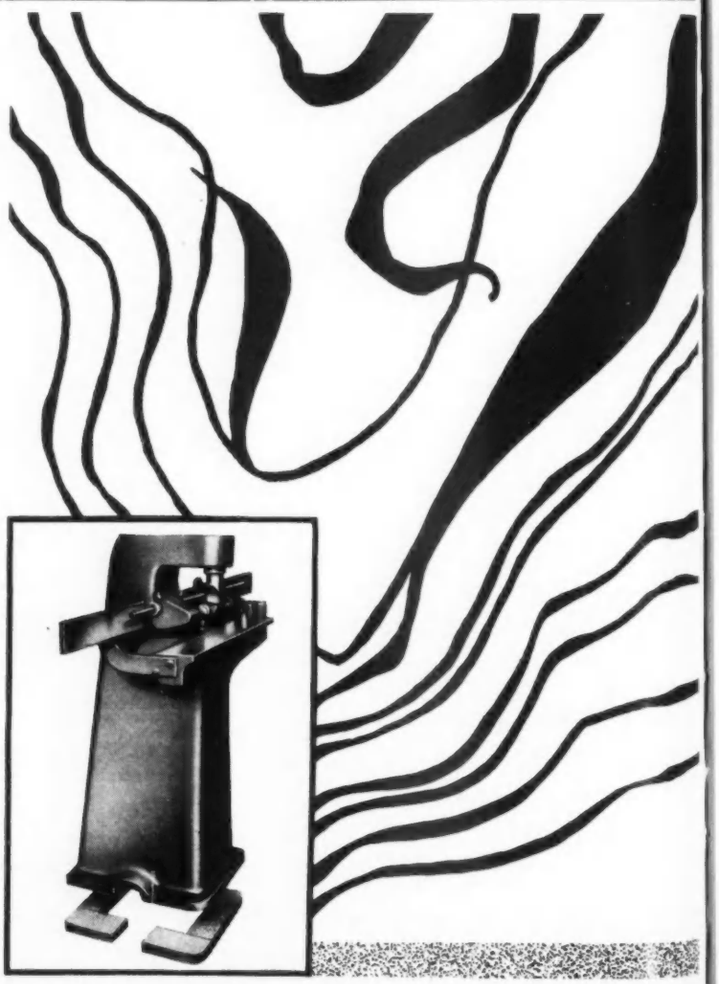

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THE ENGINEER

No. 5477 JANUARY 13, 1961 Vol. 211

BETTER OPPORTUNITIES IN TECHNICAL EDUCATION

There is now a straight through road from school to the attainment of full technical qualifications and membership of a professional institution for all youngsters able to show that they are well-equipped with brains. They can go direct from school to a university and so acquire a degree, following up with works training or, nowadays, take an alternative route through a College of Advanced Technology, acquiring a Dip. Tech. in the process. Improvements to the educational system made since the war ensure, as far as it is humanly possible, that no youngsters mentally suited to a technical education of this standard shall be without the opportunity of having it. But for those endowed with lesser intellectual abilities the road ahead has never been so clearly defined. It has been repeatedly pointed out that every technologist needs to be aided by a number of technicians and that he is powerless to produce very much unless there are available trained craftsmen and operatives capable of understanding his instructions. Yet the tendency has been not specifically to train technicians but to draw a supply from those who might write after their names "failed B.Sc." or "failed Higher National Certificate"; or from that sad and very numerous group of people who, having entered upon a N.C. course, have become discouraged part way through and have given up; or, to a minor extent, from men who have followed a few existing courses, branching out from craft courses. Furthermore there has been a tendency to leave it far too much to chance whether those capable of benefiting from N.C. courses or craft courses, such as those organised by the City and Guilds of London Institute, actually do take them. Another defect which has become more glaringly obvious as the years have passed has arisen out of the successive raising of the school leaving age to fifteen. The origin of technical colleges lay in the desire of working men in industry for improved education. The colleges were thus founded independently of universities and schools and the courses they offer, even to this day, tend to be suited to people older than fifteen. There has thus come into being an ill-defined and undesirable gap in the educational road ahead for those leaving school at fifteen; and even for those who stay another year at school the way ahead may not be obvious. A wrong choice of the course to be followed can easily be made.

The situation is now to be changed. In a White Paper "Better Opportunities in Technical Education," issued last week, future Government policy is outlined for England and Wales and a companion document makes appropriate proposals for Scotland. The terms of the White Paper are summarised elsewhere in this issue. A major change to be brought about is that a youngster will be able to proceed straight from school to a part-time course at a technical college. That course will pick up his or her education at the point where the school left it. The educational route ahead, though no longer a route to be compulsorily followed, will be clearly defined. It can be confidently expected that more will follow it. Dependent on the talents revealed in the preliminary courses students will be guided a year or two later, and as part of a continuous process, into courses leading to the acquirement of a National Certificate, or suitable for craftsmen or operatives. Transfer between courses will be possible even to the extent of opening a way to a university. The wastage in N.C. courses has for years been depressingly high. It has been depressingly high not only for those who have mistakenly entered upon courses for which they are mentally unfitted, but also for teachers, who feel frustrated when called upon to attempt to teach large numbers of students who will inevitably fall out discouraged — to the extent of 75 per cent or more of all who enter. Initial selection procedures are to be improved and there will be a standard of entry equivalent to a pass in G.C.E. "O" level in four subjects. A course for the Ordinary N.C. will last two instead of three years and the opportunity is to be taken to widen the syllabus, particularly by including more study of English. The route via the Higher N.C. to professional status will remain open. There are to be new "General" courses intended to bridge the gap between school education and later technical education. They will provide a "diagnostic" period during which it will be possible to select for individual youngsters what will be a suitable course to enter upon later. Should it prove practicable, in the not distant future, to raise the school leaving age to sixteen much will have been learnt about the kinds of education which should be offered to those over fifteen.

The proposed changes cannot come immediately into force; but some of the courses envisaged will be available as from September this year, notably a new technician's course in mechanical engineering. Courses of the same kind in electrical engineering and telecommunications are already available. The provision of other courses is being pressed forward urgently and institutions, technical colleges, the City and Guilds of London Institute and

many engineering and other firms are enthusiastically and energetically co-operating. But there is much to be done. If really satisfactory general courses are to be derived there will need to be collaboration between technical colleges and schools — an excellent development in itself. Some guidance may be available from those who operate "preliminary" courses in evening institutes, as well as larger establishments. Colleges will also have to review and amend existing syllabuses and courses and introduce new ones. Together with industry they will have to derive new operatives' courses and make arrangements for providing new or amended C. and G. courses for craftsmen and operatives. The City and Guilds of London Institute will be and is, indeed, already heavily involved and the modification of N.C. courses will continue to require the detailed attention of the Ministry and professional institutions. If the scheme is to prove a success there will need to be substantial co-operation from industry. The White Paper suggests, for example, the extension of the time available per student per year on part-time day release from 220/280 hours to 330 hours. Possibilities are that the number of separate days of release might be increased or that there should be block release over a period of weeks (an arrangement which might permit a firm to release half of its apprentices for a given number of weeks followed by the release of the other half when the first lot returned); or even the arrangement of sandwich courses. There is also the possibility that colleges might take over some of the craft instruction now given in many works in special apprentices' schools. We foresee nothing but good to come out of increased collaboration between industry and technical colleges. It will be observed that a good deal still needs to be worked out in detail, that almost all still needs to be put to the test of practice and that much that is done will have to be somewhat experimental. But the scheme as a whole is an inspiring one and it appears flexible enough in conception to permit any initial mistakes that may be made to be quickly corrected.

STEEL LOOKS AHEAD

In 1960 the production and exports of the British iron and steel industry reached record levels. Of that it is justifiably proud. But the industry is not content to rest on its laurels. On the contrary it is much more interested in the future. Nobody could accuse it of facing its future timidly. Having spent £900 million on development since the war, it has already decided to spend at least a further £450 million by 1965. It is keenly aware of the fact — sometimes overlooked — that in this developing world an industry either goes forward or backwards; it cannot stand still even if it wants to. The steel industry is determined to go forward and its decision augurs well for all of us, for it is not only a supplier of materials fundamental to an industrial economy; it is also a very large and important user of raw materials, services, and skills which are the basis of livelihood for a large number of people. There will not be wanting those who, in their determination to make the worst of any situation, will protest that the industry's plan is too ambitious, that the present time is rather one for consolidation than expansion. They will point to the many difficulties that the future will bring. Increasing competition from other materials, and from nations which have either established new steel industries or have greatly augmented existing ones, will be put forward as reasons for doing something different, or even for doing nothing at all.

Of course there are, and will continue to be, difficulties. Nobody knows that better than the steel industry itself. That it knows full well the problems it has to face, and says so, publicly, is one of the outstanding features of a live industry. For to recognise clearly any problem is the first essential step towards its solution. To have plans ready to deal with the situation as it develops is the next essential, and here again the steel industry is not found wanting. As to its ability to put those plans into action, and to adjust them as circumstances demand, it has done so with conspicuous success in the past, and even the most pessimistic of beings would find it hard to produce reasons why the industry's planning and technical skill should leave it suddenly. That the steel industry has confidence in its own future should be sufficiently obvious. But does it base that confidence on anything solid, anything which can be factually determined? Even a brief examination of the main facts shows that British steel has a very solid basis for its assessment of its own future. In the first place, what of the potential market? Steel consumption per annum per head of a country's population is a very good measure of that country's standard of living. On this basis the world leader is the U.S.A., with 1244 ingot pounds per head per annum (1957 figures). Canada, Sweden, Germany and the United Kingdom follow, in that order, and at the bottom of the list are countries with figures as low as 11 lb. or even 8 lb. In between these extremes there are many countries whose steel consumption must rise if they are to achieve even a reasonable standard of living. Even the U.K. market is far from saturated. There is an enormous potential in existence, and there is no reason why, given even half a chance, the British industry should not have its share.

To get that share, however, it must offer, both at home and abroad, products which are of high (and increasing) quality and variety, at a price which the customer will pay. It must make use, too, of what raw materials it can get, which are not always what it would like. Can it surmount these hurdles? British steel has a reputation for quality second to none, and the industry is constantly striving not simply to maintain but to improve its standards. In the matter of cost it has a more difficult task. Costs of raw materials (and quality, which is often of equal importance) are sometimes beyond its control, and it pays, rightly, much higher wages than some of its overseas competitors. There is only one answer — efficiency. In its extraordinary willingness to accept technical change (and this applies equally to managements and men) the industry has, in the past, found the way to efficiency. It is now repeating its past performance, only at a much faster rate. Technical changes, bringing greater productivity, lower costs, and using poorer raw materials, while at the same time maintaining or improving quality, are proceeding at such a rate as to be quite bewildering to those outside the industry. All these things add up to one simple fact. Steel not only believes it can, and ought to, go ahead; it is going ahead. The least we can do is to wish it well, for its continued progress will benefit all and can harm none.

WHAT IS TRAFFIC ENGINEERING?

The writing of "Retrospect and Prospect" for last week's issue recalled to us the traffic engineering furore of a year ago. Astonishing now to recollect its dimensions! The House of Commons took notice of it to the

extent of devoting a full-length debate to an activity of which the Joint Parliamentary Secretary to the Ministry of Transport, Mr. John Hay, was constrained to remark: "To put the matter in perspective, I must remind the House that traffic engineering is not in itself a profession; it is a branch of the much wider profession known as highway engineering." He refrained from extending the perspective to embrace civil engineering; the House had shown that, in its estimation, traffic engineers — if only they existed — could be very important people, well worth debating; their complex professional background was of less concern to legislators while the foreground remained unpopulated. To-day, ten months later, so far as we are able to discern, that foreground still remains little populated; there are still far too few traffic engineers: which is something we may now seem to have anticipated when writing on the status of traffic engineering in our issue of May 13, 1960.

We turn next to discuss the one symptom of a continued, country-wide interest in the subject, namely the Traffic Engineering Study Group of the Institution of Civil Engineers. The Institution has kept the Group open to a wide membership, not exclusively professional, and has continued to rate its proceedings informal, thereby ensuring freedom of discussion without, we trust, detracting too much from the interest of the proceedings as reported in this journal. In fact, a high proportion of the anonymous speakers in these reports have been of great eminence in the highway and the traffic world. The four meetings the Group has held so far this winter have drawn large attendances and can be said to have been lively affairs — as professional meetings go. However, we wonder whether the matters debated by the Group are always sufficiently important to warrant airing at this, the national forum. They are of interest certainly, for the minutiae of traffic engineering are curiously engrossing; but is it not rather a pity that a body of this calibre, many of whose members have faced long wintry journeys from the provincial centres in order to be present, should spend its time on details (often it has seemed to us highway details rather than traffic engineering details), almost never on principles: on doctrine, never on policy? We realise that the Group, elastically constituted as it is, may be diffident about regarding itself as a "body" at all, let alone one able to make pronouncements upon important matters. But there seems to be no other independent body remotely competent to influence the course of events in traffic engineering in this country. Advisedly we mention the "course", not the "progress", of traffic engineering, for progress can hardly begin until a host of local authorities have set up traffic engineering departments and succeeded in attracting men (and women?) into this calling. Those councillors, engineers, police and private individuals who are trying to get their local authorities properly interested in traffic engineering might find it a great help to be able to quote pronouncements of the group; but that is moving on beyond the immediate question we have posed ourselves, on the possible widening of the scope of the group's deliberations.

At its next meeting, on January 26, the Group will discuss the work of the Graduate School of Highway Engineering, University of Birmingham, where the studies include traffic engineering together with highway engineering. Now we do not doubt that an entire evening could be devoted, not unprofitably, to discussing the syllabus and curriculum; but the choice of this subject for a meeting immediately agitates in our mind a broader question which vexes us. It is whether the present link, in this country, between highway engineering and traffic engineering is intrinsic and vital, or artificial and harmful? Do traffic engineers really need to be bothered with the study of civil engineering subjects? It is a question that was set and then largely begged at the Civils' discussion on the place of traffic engineering in the Institution, reported in its proceedings for July 1959, Volume 13; the minor question of whether a spell of traffic engineering should help a civil engineer to qualify for membership of the Institution attracted more attention, and many speakers treated the linkage as a *fait accompli*. Of course the linkage, if it continues, must inevitably hamper the more immediate growth of traffic engineering in this country as there will be a shortage of fully qualified practitioners; and that is a situation to be endured if the principle is sound. But is the principle sound? Are highway engineering and traffic engineering truly in affinity or are they, conceivably, mutually repugnant? The latter idea may be nearer the truth. Consider, for example, the apparent liking amongst highway engineers for roundabouts. But to traffic engineers they may be anathema since they offer hindrance to free traffic flow. Those are the sort of fundamental questions on which we should like to be able to look to the group for enlightenment. To be specific we revert to Mr. Hay's perspective of traffic engineering as a branch of highway engineering and ask the group to express its views on whether it provides a healthy environment for the development of British traffic engineering. It is a question that, we freely admit, we should not like to be asked to pronounce upon for the present.

The Engineer—100 Years Ago (JANUARY 11, 1861)

"NOTES FROM THE NORTHERN AND EASTERN COUNTIES"

"An important experiment has been made on the Grand Junction Canal with a new canal steamboat, having an engine of 6-horse power driving a screw, designed by Mr. Burch, of Macclesfield. The boat and her engine had been previously fully tested in trips between London and Birmingham; she had been found capable of towing 300 tons, and her general 'behaviour' was excellent.

"Her appearance is that of an ordinary fly-boat, a boiler and engine being fitted near the tiller; but in improved vessels of the same kind, an endeavour will be made to prevent loss of stowage by placing the cabin above the machinery. In the trip on the Grand Junction the boat traversed six miles in an hour and a half (the number of locks being five), the journey occupying in ordinary course two hours and three quarters. The saving of expense as well as of time was also exceedingly important, horse labour costing at the rate of 6d. per mile, and the steam only 2d. The Pioneer—as this experimental boat is called—was built in accordance with the patented plans of Mr. Burch, and has his peculiar convergement in the buttock lines to a circle of the same diameter as the central disc of his screw propeller, which he calls the dead circle, because in a true helix the angle within its radius is too coarse for effective action, and when those parts, as in the ordinary screw are exposed, they not only render no service, but become obstructive and waste a considerable percentage of power.

"The fin blades are attached to the periphery of the disc, commencing with a suitable angle for propulsion. By this arrangement propellers of small diameters can carry four effective fin blades, and, being driven without wasting power at a moderately high speed, the full force of the engine comes into effective action on the water."

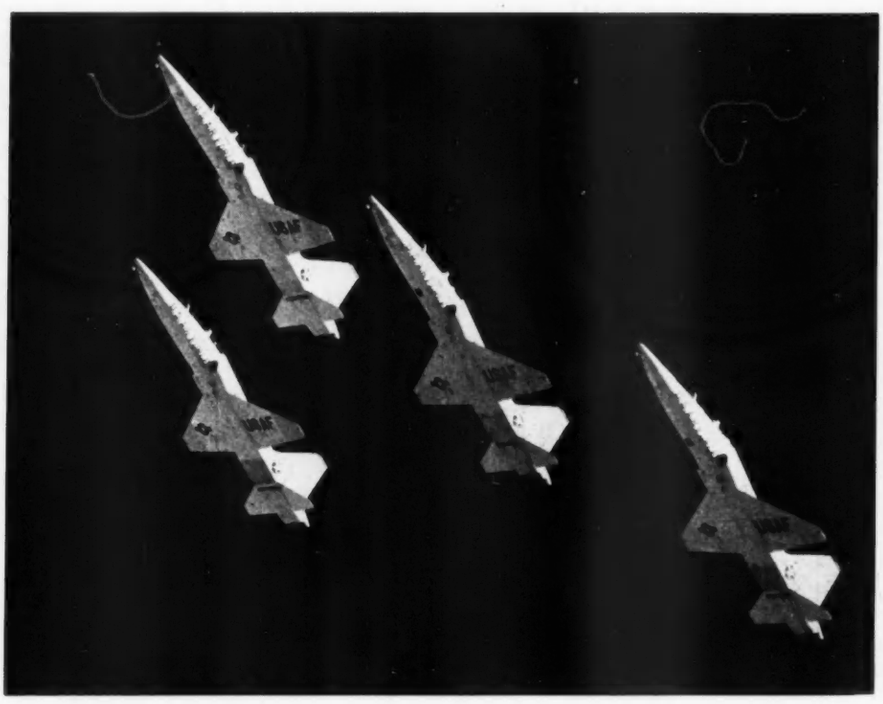
Aeronautics in 1960

A REMARKABLE trend that became apparent as 1960 ended appears to be a realisation that the assessments of the future that prevailed at the beginning of the year were ill founded. It has been observed that in many countries investment in aircraft is continuing, and yielding significant progress, and that the demand for the ultimate product, seat-miles or ton-miles, is growing in its accustomed way. So far, however, this change from a negative to a positive approach has not been confirmed by the undertaking of actual construction and, of course, it may not persist; the woefully belated optimism of, for instance, the President of the Society of British Aircraft Constructors may be explained on the basis that those member firms who subscribe to the conservative view have got out of the industry, so that those remaining must be comparatively sanguine. Nevertheless, it is not to be denied that large and important firms not only entertained, but also acted upon, policies of retrenchment, and there remain the questions of whether what remains of the industry can continue in existence and, much more important, whether it is able to provide whatever may be needed in this country and is not available from abroad.

A touchstone, possibly valid, as to the viability of the surviving industry is offered by the high-performance v.t.o.l. aircraft. To our knowledge, what studies have been made have confirmed rather than contradicted our submission in the last article in this series that what is now feasible is a small supersonic aircraft with thrust slightly in excess of its end-of-mission weight and a control system allowing vertical landing; zero-launching of such a machine should present little difficulty. The usefulness of such a machine would seem beyond dispute; the Royal Navy has allowed the replacement of the "Sea Vixen" to be delayed until another interim fighter along conventional lines could barely be justified, and now that all the N.A.T.O. and Commonwealth services have selected supersonic equipment which does not offer deck-landing capability it is apparent that the Royal Navy will have to develop one for itself. An explanation of this anomaly, that an obvious and imperative demand should find no contractor proposing to fill it, can be found in the inadequacy of the industry. There are to-day in this country but four firms established as builders of aircraft for the fighting services. One of these four, the British Aircraft Corporation, is engaged on building a strike aircraft which lands and takes off in the conventional way, and the company stands, therefore, to lose, at least in respect of repeat orders, if the prevailing view that jet engines compatible with v.t.o.l. have yet to be constructed is abandoned. Handley-Page, Ltd., while it has shown itself very ready to grapple with unconventional aerodynamic solutions, has for long been occupied with aircraft for entirely different roles and would probably be justified in believing that this is not the best use that could be made of its staff. Hawker-Siddeley Aviation, Ltd., includes a subsidiary with a naval aircraft in production, but this group eschews manned supersonic flight. Finally, there is Short Brothers and Harland, Ltd., long associated with sea-flying, and with at least some interest in v.t.o.l.; an explanation for the attitude of this firm is not apparent, but it may be sought in the consistent tendency for the firm to interest itself in projects originated elsewhere. Thus it appears that there is here an early example of the "rump" of the industry being unequal to even an assignment of immediate importance, and it remains to be seen whence the Royal Navy will procure a modern fighter for use from carriers of modest size.

Consideration of extremes of performance such as runway-less operation draws attention inevitably to one of the most characteristic features of aeronautical thinking in this country, an overwhelming reaction against the integration of the "lift" and "thrust" systems of aerodynes. The one example of an aircraft demonstrating, at least in some modes, such integration, the "Rotodyne," has signally failed to retain its sponsors' confidence, while there are numerous aircraft projected, or under construction, in respect of which it is admitted, or even claimed, that the wing and the engines are as separate as can well be. The reasoning here is that by this approach the ultimate performance of each of these entities can be realised; this is, of course, not to be confused with attaining the ultimate performance of the aeroplane, and the difference between the two approaches can perhaps be exemplified by pointing out that in one important régime, that of landing, the engines will be playing little part under the philosophy of "keeping things separate." It is, of course, true that the present generation of jet aircraft are inclined to be critical at take-off, but to be capable of executing a missed approach with two engines out (if four-engined), but it cannot be denied that the landing is rendered easier by the fact that runway length provided for taking off is generous.

Closely related to this question of the philosophy of aircraft design is the problem of landing the aircraft. Conventional aircraft approach at a speed dictated rather by the minimum drag speed than the stalling speed or even the minimum flying speed, and hence improvement in C_{Lmax} or L/D is not reflected in a reduced approach speed. There is thus a strong incentive to introduce automatic systems to allow flying below the minimum drag speed, and there has now established itself a school of thought which would regard an entirely automatic landing as acceptable for normal operation. The virtues of such a system, when achieved, would be twofold; first, the automatic pilot should be so greatly superior to the human pilot that blind landing should be acceptable in commercial operation, thus putting an end to diversions to alternate landing grounds; and secondly, that aircraft can be flown which no human pilot could land. However, it is necessary not only to build a system of adequate capability and reliability, but also to demonstrate its performance to the satisfaction of such interested parties as the pilots and the airworthiness authorities. It appears that the only systems of which the feasibility has so far been demonstrated are co-operative, involving special equipment both in the aeroplane and on the aerodrome; since there is no clear incentive to install the ground equipment when the system has not been accepted for actual operation, the acquisition of sufficient experience to justify depending upon the system may take some years. The antithesis of this solution is to render the aeroplane so tractable that the pilots can handle it in fog, snow, dust-storms, and so on; such a performance is conceivable either with simple vertical landing or by an integration of wing and engines that effects control of lift independently of incidence, so that the inertia of the airframe ceases to



The technique of mounting the engines aft has been exploited both longest and furthest by the Northrop Corporation, and in the case of the twin-engined N-156 it is claimed to result in extreme ease of access, the engines being conveniently reached by a standing man. This supersonic aircraft exists in various versions, the formation illustrated being composed of T-38A "Talon" two-seat trainers. The single-seat "Freedom Fighter" has water injection upstream of the J-85 engines and attains about M.2

The North American X-15 research aircraft has now made numerous flights and reached a speed of 2200 m.p.h. (M.3·3) and an altitude of 136,500ft. Re-entry from such energy levels is critical in respect to both aerodynamic stability and heat rates, and to provide the pilot with attitude information the long nose probe has now been replaced with the flow direction sensor seen here : it takes the form of a sphere with a symmetrical pattern of holes which is rotated by a hydraulic servo system to point directly into the air-stream. The operating environment of the "q ball," as it is called by its makers, the Northrop Corporation, was simulated by exposing it to the exhaust of an after-burning jet engine. The illustration also shows four of the eight nozzles of the reaction control system on the nose, and the cockpit canopy with its two plane windows. Notice the extreme travel of the landing gear, and the "up" lock at the bottom of the leg ; the gear is of course retracted before the X-15 is carried aloft

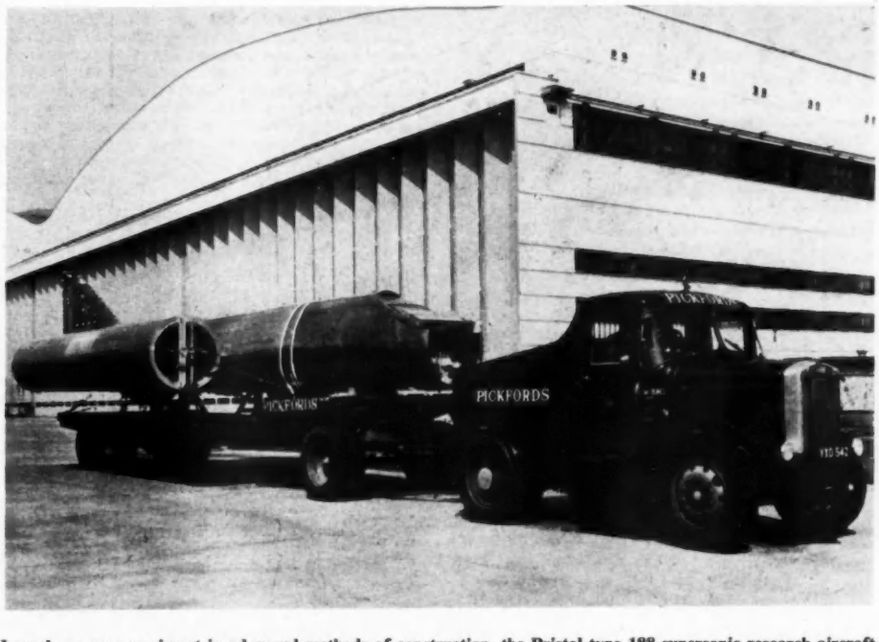
dominate the response characteristics of the aeroplane. Means proposed to this end include blowing over, through, or against the flaps, artificial generation of circulation, and the extension of the span by blowing through tubes projecting from the wing tips ; while it appears that some at least of these solutions are protected by patents, it is surprising to observe the prevailing confidence that the optimum amount of energy to be transferred from the engines to the flow about the wings is now, and will remain throughout the life of contemporary projects, zero.

Closely allied, at least in the engineering implications, to the control of lift by blowing is the reduction of drag by suction applied to the boundary layer, and here again there is evident a determined renunciation of the theoretical advantages. A superficially rational explanation can be found if one postulates that Handley-Page, Ltd., believes that there now exists so little competition that it would be needlessly venturesome to proceed with the H.P. 113, and that the Royal Air Force is so far intimidated by the magnitude of its commitments that it intends to persist in its policy of procuring only aircraft that operate well within the established state of the art.

There are, of course, no grounds for concern in a decision to embrace or reject a certain technique if the consequences of error are merely that one or two more firms go out of business. It is, however, of public interest to observe that the projects in hand in this country are emphatically limited to operation from and to well-equipped airports, but that the fighting services have neither in operation nor on order any flying machines adapted to tactical freighting : neither of the two obvious avenues of approach to a forward-area freighter, improving the flying and taxying characteristics of fixed-wing aircraft or the utilitarian qualities of the rotorcraft, are being explored. It may perhaps be in context to observe that the manifold investigations into ground effect machines have little potential application to this problem, since these vehicles are acutely sensitive to gradients not only along but also across their track, so that their movements are susceptible to prediction, and also because their manœuvrability is inherently low ; their obstacle-crossing ability, while normally poor, is susceptible to improvement by carrying reserves of energy in a form rapidly available, e.g. slow-burning cartridges. Returning to our theme, it may be apposite to remark that, while the aerodynamics of a tactical freighter may cause it to resemble in appearance an efficient medium-speed transport, military requirements will dictate a complete divergence under the skin—for instance, the use of integral fuel tanks would render the machine ridiculously vulnerable in a forward area.

The Commercial Aircraft Situation in 1960

A large proportion of the transport aircraft in service to-day continue to be of the older piston and turbo-prop types which have served the airline industry so well for many years. However, during the past twelve months the new jets have established themselves as the competitively-significant first-line equipment on the majority of trunk routes. While these first generation jets have been making rapid—and, on the whole, astonishingly incident-free—progress bedding themselves down operationally, they have also given convincing evidence of their ability to "show-off" the propeller types in the airlines' fierce competition for revenue. On routes all over the world—although so far still predominantly on the longer hauls—jet load factors have been high, despite the marked step-up in vehicle size provided by the new aircraft, while traffic on competitive services flown with propeller aircraft has suffered increasingly. The passenger appeal of the jet, which was first demonstrated by B.O.A.C. with the "Comet" on the routes to Africa and the Far East in 1952–53, has now been confirmed beyond question. At the same time, the economics of most of these radically new aircraft have not proved as unsatisfactory as some prophets of gloom foretold. Indeed, the indications are that the operating costs of particularly the



Largely as an experiment in advanced methods of construction, the Bristol type 188 supersonic research aircraft has been built of stainless steel, principally weldable FV-520. The first example is being devoted to structural testing and is seen here at Filton before carriage to R.A.E., Farnborough. Comparison with the Scammell tractor shows that the single-seater is by no means small; it is, in fact, rather larger than a F-105 "Thunderchief"

larger versions of the Boeing " 707," of the " Caravelle " and of the various models of " Comet 4 " are working out only slightly above estimates and should, in due course, at their differing economic levels earn good profits for their operators. The DC-8 continues in some trouble with modifications being made retrospectively in attempts to make good certain deficiencies in its performance but, although its economics have suffered from this setback, there is no reason to believe that this aeroplane—and, when they have accumulated enough hours, the Convair CV-880/990 series also—will, in time, win through to commercial success.

The fact is that even these first generation jets, the majority of which have single-flow compound jet engines of relatively high specific fuel consumption, are already proving reasonably economic, at least on routes where there is sufficient immediate traffic for their larger capacities. Once they are properly worked into high-intensity service, they should be able to offer some reduction in unit operating costs over their propeller-driven predecessors. Those airlines which, by their example, launched the industry into the " jet buying spree " in 1955–56 cannot have hoped for more than this. With the further developments of the jet engine now in prospect, really worth while advances in operating economy and consequential further reductions in fares and expansion of the business should, in due course, become possible. It is already becoming clear that the airlines' swing to jets was not the irresponsible action which some critics claimed.

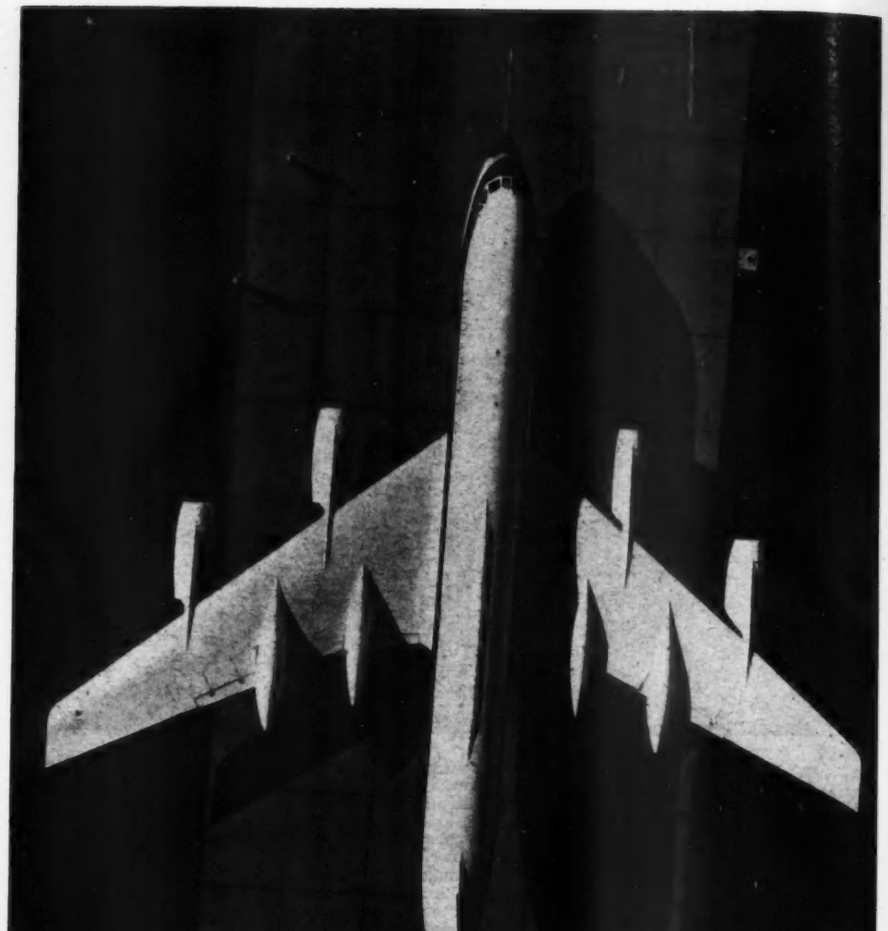
While these important developments have occurred on the routes, where the final test must always be, a gradual revolution has also been taking place in the minds of those more progressive operators who play a key role in shaping future aircraft policy. This revolution in thought is largely the consequence of progress with the more advanced designs of jet engine since the jet buying era started in October, 1955. At that time, although Rolls-Royce, in contrast to Armstrong-Siddeley, had even then been advocating dual-flow engines for a considerable time and was engaged in the development of the " Conway " by-pass engine, the possibilities of development in this direction had yet to be fully demonstrated. At that time also the turbine had still to establish the much higher standards of reliability which it has to offer and the considerably longer overhaul lives, with all that these imply in lower engineering costs.

It has been clear for some time that many of the large first-generation jet airliners—particularly those with their engines in pods—would in time be re-engined with dual-flow engines and that all the later larger jet transports would adopt this type of power unit from the start. However, it now seems that the jet engine may much sooner than was at one time thought possible prove to be the best answer down to even the smallest and shortest-ranged feeder types of transport aeroplane. Thus, although the turbo-prop will undoubtedly have a much longer and more useful innings on the shorter hauls than it has proved capable of providing on the longer routes, the indications are that even on the shortest hauls it may quite soon be proved inferior to the remarkably small, light and efficient dual-flow jets which are now in prospect. The signs are, in fact, that the jet may take over in the majority of transport aircraft built after about the mid-1960s.

Use of these engines in all transport aircraft will raise operating speeds to at least M.0·75 and those of the larger types to between 0·8 and 0·9. Somewhat lower speeds than the immediately subsonic régime of the larger trunk-route airliners will probably be selected for the smaller and shorter-haul types because high cruising speeds give small benefits in savings in journey time on short sectors while the greater wing sweep required for the higher subsonic speeds makes it difficult to offer the good low speed characteristics and short field performance which is essential for the shorter-haul applications.

Considerable progress is, however, being made in improving maximum lift coefficients of swept wings. The unswept wings of propeller driven transports have, in practice, been giving C_{Lmax} of between 2·5 and 3·0 by the use of double slotted or Fowler flaps. (This compares with a C_{Lmax} of 1·5 for unflapped wings). However, the first swept-wing transports have suffered from a decline in maximum lift coefficient to 2·0 or even less. This loss is now being won back by a combination of improved detail design of trailing edge flaps and the use of leading edge slots or nose flaps. However, as suggested above, it may well be that even the best of simple swept wings will prove unable to meet the conflicting requirements of cruise and of landing and take-off, and that the engines will be used to modify the flow about the wings.

In spite of the widespread study now going on in several countries of supersonic transport projects, it seems unlikely that the airlines will be ready to make use of such developments before the mid-1970s. The airlines have become so heavily committed to subsonic jets that they are unlikely to be able to face such a major step in re-equipment until they have had ten years or more to write off current types.



The Convair 990 is the first " second generation " jet airliner, with a thinner and more highly swept (39 deg. at the leading edge) wing than any other transport. Its maximum cruising speed is intended to be 640 m.p.h., and it will be certificated to operate at M.0·91. At this speed the flow over the wing is naturally supersonic, but the drag penalty associated with operation beyond the critical speed is mitigated by a technique that affords a particularly clear exposition of transonic area rule. On the upper surface of the wing are fitted capsules (containing fuel), and the maximum cross section is thereby moved back to the trailing edge; thus the shock wave detaches the boundary layer over only a very small surface area and not a large proportion of the wing upper surface. As the shadows show, the capsules are shaped to lie above the wing chord, bringing them as close as possible to the areas where their influence is required. To improve the performance of the wing at the opposite end of the speed range it has both leading edge flaps and slats, and slotted Fowler (area increasing) flaps ; the unusually large spoilers are evident in the picture. The stalling speed in the landing configuration is expected to be less than one-sixth of the maximum speed. Notice the very large (6ft diameter) pods enclosing the General Electric CJ-805-23 power plant, the unique simple-cycle ducted fan engines

In addition, that the air-lines will be prepared to buy high-cost supersonic aircraft for operation at premium fares, seems to be an unlikely development. The airlines have never previously ordered new equipment that does not promise operating costs at least as low as those of current equipment. Advances in knowledge should, in due course, reduce the operating costs of the supersonic transport to an acceptable level but the airlines are unlikely to be interested until there is real promise of competitive economics being achieved.

Many other uncertainties still exist about the operation of large supersonic aircraft which are likely to make the airlines hesitate. Quite apart from the operational problems—of which air traffic control will probably be one of the most intractable—the question of the sonic boom may prove to be a major difficulty. It has even been suggested that supersonic transports may be able to operate only over the sea or uninhabited regions. Such a restriction would gravely limit their utility.

The most serious uncertainty in supersonic developments relates to the question of design cruising speed : should the airframe be built in conventional fashion of light alloy, in which case its cruising speed will be limited to about M.2·2 (1450 m.p.h.) or should the revolutionary step to new structures in steel or titanium be taken, thus making possible much higher speeds ? Developments of current jet engines would probably suffice for a M.2·2 design but entirely new power plants are likely to be required for higher speeds.

An airframe in steel would offer an acceptable life at speeds of M.3 (2000 m.p.h.) or more but limitations on the operating temperature of other materials which would have to be used in such an aeroplane seem likely to hold down its speed to perhaps M 2·7 (1800 m.p.h.), at least initially. There are, in fact, sound technical arguments for limiting the first generation of supersonic transports to light alloy aircraft designed to cruise at about M2. Indeed, it seems unlikely that enough is known yet for anything more ambitious to be attempted in any country. However, technical considerations are not the only ones which have to be considered in undertaking a supersonic transport programme. The United States, and possibly the U.S.S.R., are developing large, long-range military aircraft in steel designed to cruise at speeds in the M.3 range. If they find themselves in a position to undertake transport aircraft in steel on the background of their military experience soon enough for them to be able to meet the airlines' requirement for a supersonic transport from the mid-1970s, an earlier light alloy development with its permanent limitation in cruising speed would be doomed to failure if it could itself be developed only in time to enter service in the early 1970s.

There are indications that, for purely technical reasons, Britain is contemplating an early start on the development of a M.2 supersonic transport in light alloy. In view of the country's limited experience in the supersonic field, there is little doubt that a steel transport is, in fact, beyond its capabilities and will so remain, at least for a considerable time. This is not, however, a sufficient reason for undertaking the less ambitious project. Indeed, such a programme is likely to prove a disastrous waste of money if it is overtaken by developments in steel abroad.

Transport Helicopters.—Important events in 1960 have been the initial flights of the first two really practical transport helicopters. Both are American designs. Although the first multi-engined helicopters flew as long ago as 1946, it is only with the advent of suitable gas turbines that potentially practical multi-engined transport helicopters have begun to emerge. The first multi-turbine helicopters to fly included the Bristol " 192 " and the Vertol H-21D and V.105, which were derived more or less directly from previous piston-engined helicopters, but probably the most significant and certainly the most practical transport designs are the more recent tandem-rotor Vertol V.107 (which first flew on April 22, 1958) and single-rotor Sikorsky HSS-2 (which made its first flight a year later, on March 11, 1959). Rather more than a year ago developments of these two designs—known respectively as the V.107/II and the S.61L (which is similar to the HSS-2 except for a longer forebody)—were ordered by the three scheduled helicopter airlines in the United States for service from the summer of 1961.

The prototype of the Vertol V.107/II, a converted YHC-IA military prototype, flew for the first time on October 25, 1960, while the first S.61L followed on December 15, 1960. Development and certification flying of both types is now proceeding rapidly and production deliveries are scheduled during the next six months.

As first operated, the V.107/II and S.16L will probably be flown on a " contact flying " basis only by all three operators in much the same manner as the smaller single-engined helicopters which have preceded them. This is because the single-engine performance of the early versions of these aircraft will be marginal, and instrumentation, radio aids and operating experience are unlikely to be sufficient for immediate full-scale instrument operations. At the same time, the operating costs of the new aircraft —which will accommodate twenty to twenty-five passengers—will still be too high to make possible immediate fully economic services without subsidy. However, the important thing about these aircraft is that, after a period of further development and as improved aids and greater operating experience becomes available, it should be possible to graduate in stages to full all-weather operations down to visibility and cloud ceiling minima at least as low as those which presently apply to fixed-wing operations.

It is interesting that normal competitive influences should have brought two entirely different designs of American helicopter to comparable stages of development at about the same time and that they should have both been offered in closely similar transport versions as alternatives for the three helicopter airlines. Even more interesting is the fact that two of the operators—Los Angeles Airways and Chicago Helicopter Airways—should have chosen the S.61L and one—New York Airways—the V.107/II. As a result, there will be established two entirely different types of competitive helicopter into airline service more or less simultaneously.

It is unfortunate that there is no prospect of scheduled services in this country with an equivalent British helicopter for several years. Although the Westland–Bristol 192 " Belvedere " flew for the first time on July 5, 1958, and the first deliveries of this helicopter have recently been made to the R.A.F., it is unlikely that the projected Bristol 192C version can be developed to adequate standards for civil scheduled operations before 1963 at the earliest. The American helicopter airlines are thus going to establish an important lead in operating experience over anything in this country.

Technical Reports

Wind Tunnel Tests on the Use of Distributed Suction for Maintaining Laminar Flow on a Body of Revolution. By N. Gregory and W. S. Walker. Reports and Memoranda No. 3145. H.M. Stationery Office. Price 11s. 6d.—Experiments were carried out in the N.P.L. 13ft by 9ft wind tunnel on a 15ft long body of revolution of fineness ratio 10 : 1. Observations were made of the effects of Reynolds number, yaw, and of isolated excrescences on the position of transition on the solid body, and the possibilities of increasing the extent of laminar flow by means of area suction were examined.

At zero angle of yaw, the maximum Reynolds number at transition on a solid version of the body was 4,500,000. When the body was set at a small angle of yaw, the transition position was much farther forward along certain generators of the body than on others, owing to the instability of the three-dimensional boundary layer. The critical heights of small conical excrescences which just precipitated transition were found to be much the same as those required on a two-dimensional aerofoil.

The " suction " version of the body was porous over the central third of the length and was attached to the overhead tunnel balance by means of a porous wing. There appeared to be no fundamental difficulty in obtaining extended laminar flow over the body with distributed suction up to a tunnel speed of 80ft per second. Above this speed, the skin joints were too rough, and numerous wedges of turbulence originating from the joints spoiled the laminar flow. The adverse effects of yaw which were noticed on the solid body were not encountered and far-back transition was obtained with the same suction quantity as was needed at zero yaw. This suction quantity was large ($v_0/U \simeq 0{\cdot}0009$ on the body), because of the rough surface.

The suction applied at the wing-body intersection (locally $v_0/U_\infty \simeq 0{\cdot}003$) reduced the secondary flow in the boundary layer and enabled laminar flow to be maintained in this region at a wind speed of 80ft per second despite experimental difficulties over awkward skin joints. Even with laminar flow right round the intersection to the trailing edge of the wing, the laminar wake from the wing rapidly became turbulent downstream of the trailing edge and gave rise to a spreading wedge of turbulent boundary layer on the body. Further investigation of this difficulty would best be carried out on a simple part model, such as the junction of a stub wing with a flat plate.

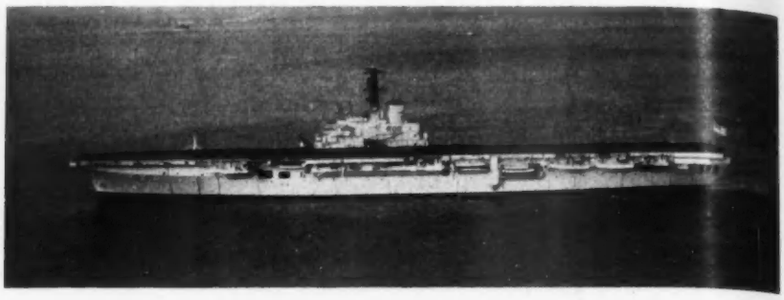
Partly in consequence of the large suction quantity needed for laminar flow, and partly because the flow on the body in the wake of the wing and aft of 0·82 of the body length remained turbulent when suction was applied, there was only a small reduction in the effective drag coefficient of the model with suction. The analysis shows, however, that the potential gains at high Reynolds numbers would be large, provided the porous surface were satisfactorily smooth and extended sufficiently far back to enable full-length laminar flow to be achieved.

Deposition of Fission Products from Distant Nuclear Test Explosions : Results to Middle of 1960. U.K. Atomic Energy Authority Research Report No. A.E.R.E.-R3349. H.M. Stationery Office. Price 2s. 6d.—This report deals with the continuation of the survey dealt with in Report No. A.E.R.E.-R3094 (which gave results up to the middle of 1959). In this survey the collection of rainwater samples for analysis has continued at seven stations in the United Kingdom and seventeen elsewhere. Samples are collected monthly at Milford Haven (Pembrokeshire) and Abingdon (Berkshire) and quarterly at the other stations and are analysed for strontium-89, strontium-90 and caesium-137. The total deposition of strontium-90 at Milford Haven in the year ended June, 1960, was found to be 2·55 millicuries per square kilometre compared with 7·1 millicuries per square kilometre in the preceding twelve months.

The report also gives some information on the uniformity of the strontium-90 concentration in rain over the United Kingdom, on the variation of strontium-90 concentration with latitude, on the ratio of caesium-137 to strontium-90 and on the seasonal variation of activity in rain.

Measurements of the Velocity at the Vortex Centre on an A.R.I. Delta Wing by Means of Smoke Observations. By A. P. Cox. A.R.C. Current Paper No. 511. H.M. Stationery Office. Price 1s. 6d.—Measurements have been made by using a smoke technique of the axial velocity near the centre of the leading edge vortex on a delta wing of aspect ratio 1 at $\alpha = 20$ deg. By simultaneously breaking trails of smoke at the vortex centre and in the free stream and analysing a film of the result, it is shown that the velocity at the centre is at least 40 per cent higher than free stream. Near the trailing edge the velocity at the centre decreases rapidly to approximately free stream velocity.

Aircraft Carriers



H.M.S. "Bulwark" RIGHT, was converted into a "commando carrier" by H.M. Dockyard, Portsmouth, in 1959-60 for the operation of sixteen helicopters. Eight of her 40mm. anti-aircraft guns were suppressed to provide space for four assault landing craft carried at built-in gantries. With a displacement of 22,000 tons standard and 27,000 tons full load she has an overall length of 737ft 9in and an extreme breadth of 123ft. She is armed with eighteen 40mm anti-aircraft guns. Parsons geared turbines of 78,000 s.h.p. turning two shafts give her a maximum speed of 29·5 knots.

"Clemenceau" BELOW LEFT, the first aircraft carrier designed and built from the keel up as such in France. Her construction incorporated an angled deck 8 deg. off the centre line, two lifts, one of them on the starboard deck edge, two steam catapults and two mirror sight deck landing aids. Built at Brest Dockyard, she has a displacement of 27,307 tons normal and 30,000 tons full load with an overall length of 845ft, an extreme breadth of 151ft, and a capacity of sixty aircraft. Her armament includes eight 3·9in automatic anti-aircraft guns in single turrets, and she is protected by armour on the flight deck, hull (over machinery spaces and magazines), island superstructure and bridges. The main propelling machinery consists of Penhöet geared turbines taking steam from six boilers and turning two shafts, aggregating 126,000 s.h.p. and developing a speed of 32 knots. With a complement of 2700, including 179 officers, she commissioned for operational service in 1960. Her sister ship "Foch" is being completed.

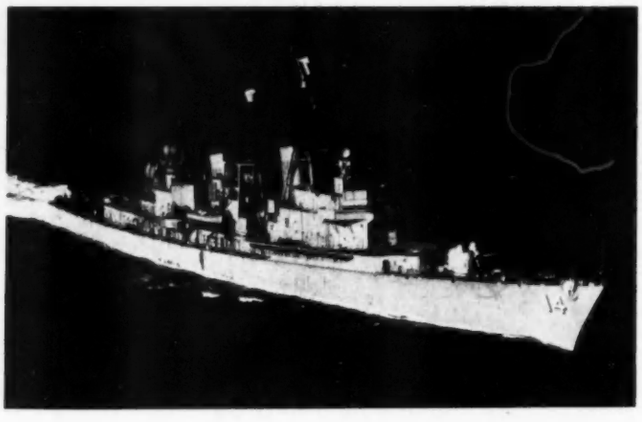
BELOW RIGHT "Minas Gerais," Brazil's first aircraft carrier. This ship was formerly H.M.S. "Vengeance," originally completed by Swan, Hunter and Wigham Richardson, Wallsend-on-Tyne, in 1945. At the end of 1956 she was sold to Brazil, and from 1957 to 1960 she was reconstructed at Veroime Dock, Rotterdam, the conversion and overhaul including the installation of the angled deck, steam catapult, mirror sight deck landing system, and complete armament fire control and radar equipment. She now has a displacement of 15,890 tons standard and 19,890 tons full load with an overall length of 700ft and an extreme width of 121ft. Her main propelling machinery comprises four Admiralty three-drum boilers and Parsons geared turbines turning two shafts and developing 42,000 s.h.p. equal to a maximum speed of 25 knots. With her huge combined angled deck and mirror sight sponson overhanging the port side, her remodelled prow, lattice mast, squat raked funnel, modified bridges, and armament mounted on sponsons both fore and aft and high up on the considerably enlarged starboard island, she presents a very different appearance from her former days as an orthodox axial deck carrier. Commissioned at the end of 1960, she is to be used primarily for anti-submarine warfare aircraft and helicopters.

U.S.S. "Enterprise" LEFT, the world's first nuclear powered aircraft carrier and the world's largest ship, was launched at the plant of the Newport News Shipbuilding and Dry Dock Company, Newport News, Virginia, on September 24, 1960. She has a displacement of 75,700 tons standard and 85,350 tons full load, an overall length of 1101ft 6in and an extreme width of 252ft. She will carry about 100 aircraft according to size and type. Her propelling machinery (built by Westinghouse Electric Corporation), comprises eight pressurised water-cooled nuclear reactors generating steam for a four-shaft arrangement of geared turbines aggregating 280,000 s.h.p. and developing a maximum speed of 35 knots. She has an exceptionally broad flight deck, a block island superstructure, a fully angled deck, four deck edge lifts sited three on the starboard side and one on the port, and four new catapults of internal combustion design claimed to have 50 per cent more power than steam catapults. She will be capable of steaming for five years without refuelling.

Cruisers & Missile Carriers

H.M.S. "Lion" ABOVE, the largest warship completed in 1960 for the Royal Navy, was laid down in 1942 and launched in 1944. Work on her stopped in 1946; in 1955 she was dismantled and rebuilt to a new design. With a displacement of 9550 tons standard and 11,700 tons full load she has an overall length of 555ft 6in and a beam of 64ft. Her armament comprises four 6in guns in two twin turrets, and six 3in anti-aircraft guns in three twin gunhouses. The rate of fire of the main armament, equally effective in the surface and anti-aircraft roles, is more than twice that of any previous cruisers, while the secondary battery is capable of a rate of fire comparable with the light anti-aircraft guns of the second world war. The main machinery consists of four sets of Parsons geared turbines aggregating 75,500 s.h.p., turning four shafts and developing a speed of 31·5 knots, taking steam from four Admiralty three-drum boilers.

"Giuseppe Garibaldi," italy's first guided missile cruiser RIGHT, was originally an orthodox light cruiser. She has a displacement of 9802 tons standard and 11,600 tons full load, an overall length of 613ft 6in and a beam of 61ft 8in. The new armament includes a twin launcher for "Terrier" surface-to-air guided missiles aft; four 5·3in dual purpose fully automatic guns in two twin turrets forward; and an anti-aircraft battery of eight 3in fully automatic guns, also of a new pattern, built by O.T.O. La Spezia, disposed in single turrets, four on each side amidships abreast the funnel and bridge, with a rate of fire of seventy rounds per minute. The ship is also designed to carry helicopters. Her propelling machinery consists of six three-drum boilers and Parsons geared two shaft turbines developing 85,000 s.h.p. and giving a speed of 30 knots.



U.S.S. "Dewey" LEFT, the world's first guided missile frigate, nine sister ships of which were completed or being completed in 1960. Displacement 3900 tons standard and 5600 tons full load with an overall length of 520ft and a beam of 54ft 6in. Armament a twin guided missile launcher aft for forty "Terrier III" weapons; one or two rapid fire 5in guns forward; four 3in anti-aircraft guns amidships, one twin mounting on each side; six 21in fixed torpedo launchers in two triple nests; and anti-submarine weapons including two rocket launchers and a "Hedgehog." The propelling machinery comprises four boilers and two sets of De Laval turbines of 80,000 s.h.p. or Allis-Chalmers-Fork geared turbines working at a steam pressure of 1200 lb per square inch and a temperature of 940 deg. Fah. superheat and developing 85,000 s.h.p.

U.S.S. "Little Rock" BELOW, a remarkably thorough conversion, now has only three 6in guns and two 5in guns forward. But aft she has a "Talos" twin launcher with forty-six surface-to-air guided missiles, and a very large radar aerial surmounts the after superstructure. With a displacement of 10,670 tons standard and 14,600 tons full load she has a length of 610ft overall and a beam of 66ft. Her propelling machinery comprises eight Babcock and Wilcox boilers and a four shaft arrangement of General Electric geared turbines developing 100,000 s.h.p. and equal to a speed of 33 knots. She is fitted as a flagship. Her five sister ships have all recently been converted from cruisers of the "Cleveland" class, but the six ships have not undergone a uniform reconstruction.

Destroyers and Frigates

H.M.S. "Londonderry," RIGHT TOP, an anti-submarine frigate from J. Samuel White and Co., Cowes, has a displacement of 2150 tons standard and 2560 tons full load with an overall length of 370ft and a beam of 41ft. Her armament consists of two 4·5in guns in a twin turret controlled by an electro-mechanical computer system, and single 40mm A.A. guns which will eventually be replaced by a "Seacat" guided missile launcher and director. For anti-submarine use she has two "Limbo" triple-barrelled depth bomb mortars, each of which can fire a pattern of projectiles with great accuracy, set to explode at a predetermined depth. Two twin and eight single 21in torpedo tubes are also installed. Two sets of double reduction turbines, taking steam from two Babcock and Wilcox boilers, developing 30,430 s.h.p., give a speed of over 30 knots.

H.M.S. "Lincoln," SECOND RIGHT, a new aircraft direction frigate completed in 1960 by the Fairfield Shipbuilding and Engineering Company, will also operate offensively as a destroyer. Displacement 2090 tons standard and 2330 tons full load, overall length 340ft, beam 40ft; armament two 4·5in guns in a twin turret together with a single 40mm Bofors mounting which will be replaced by a "Seacat" guided weapon launcher in due course. For anti-submarine operations a "Squid" three-barrelled depth charge mortar is installed. The ship is propelled by eight Admiralty Standard Range diesels in four engine-rooms driving twin shafts developing 12,380 b.h.p. and giving a speed of 25 knots. Her propellers have controllable pitch on their 12ft diameter blades. She has an all welded prefabricated hull.

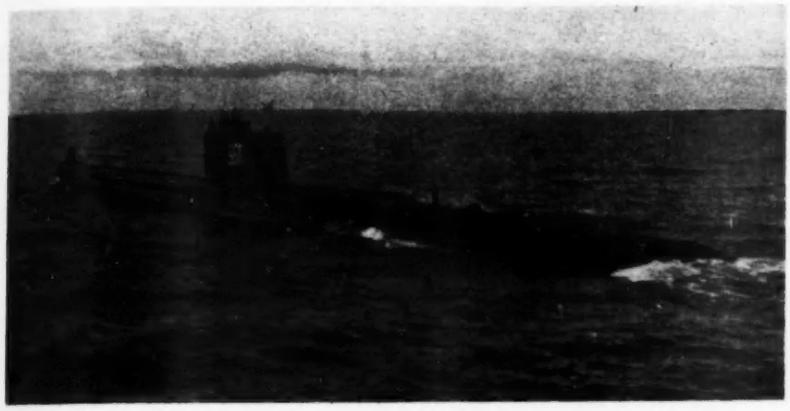
"Almirante Williams," THIRD RIGHT, the first of two destroyers built for the Chilean Navy by Vickers-Armstrongs, Ltd. Displacement 2730 tons standard and 3300 tons full load; overall length 402ft; beam 43ft. The main armament of four 4in guns is in single mountings, and is entirely automatic with a range of over 7 miles and an elevation of 75 deg. She also carries six single 40mm guns, three on each beam on an extension of the forecastle deck between the funnels, and five 21in torpedo tubes in a quintuple nest abaft the after funnel, also depth charges aft. The power plant comprises two boilers and Vickers-built Parsons geared turbines of Pametrada design turning two shafts and developing 54,000 s.h.p., equal to a speed of 34·5 knots. Her sister ship is the "Almirante Riveros."

"Akizuki," BELOW LEFT, Japan's first real post-war destroyer, completed in 1960 by the Mitsubishi Zosen Company, Nagasaki. With a displacement of 2388 tons standard and 2890 tons full load she has an overall length of 387ft 9in and a beam of 39ft 4in. She is armed with three 5in dual purpose guns in single gunhouses, one forward and two aft; four 3in anti-aircraft guns in twin mountings, one forward and one aft; four 21in torpedo tubes in a quadruple bank; two "Hedgehogs," two "Y"-guns, one rocket launcher, and two depth charge throwers. The propelling machinery consists of four boilers of the Mitsubishi CE type and two sets of Mitsubishi-Escher-Wyss geared turbines turning two shafts and developing 45,000 s.h.p., equal to a speed of 32 knots. The "Akizuki" is the flagship of Japan's "Maritime Self-Defence Force" which is not yet officially admitted to be a "Navy." Her sister ship is the "Teruzuki" also completed in 1960. They are of a new design with a long forecastle hull.

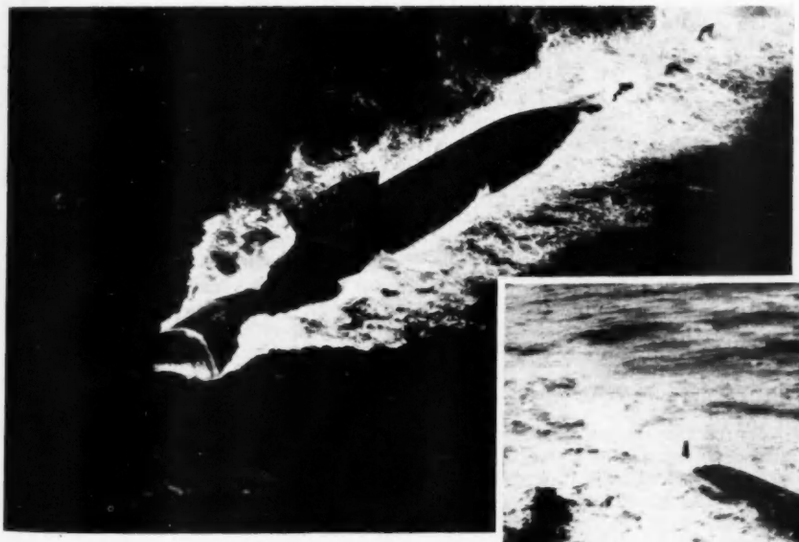
"Onami," BELOW, another new anti-submarine frigate of the destroyer type completed in 1960 by the Ishikawajima Heavy Industries Company Ltd., for the Japanese Maritime Self-Defence Force. With a displacement of 2500 tons full load she has a length of 357ft 8in and a beam of 35ft. and an armament of six 3in anti-aircraft guns in twin mountings, four 21in torpedo tubes (quadrupled); with homing torpedoes, two on each beam, two "Hedgehogs," two "Y"-guns and sonar. Geared turbines developing 35,000 s.h.p. give her a speed of 32 knots. Two sister ships were also completed in 1960, each of these three ships being built in little more than a year.

Submarines

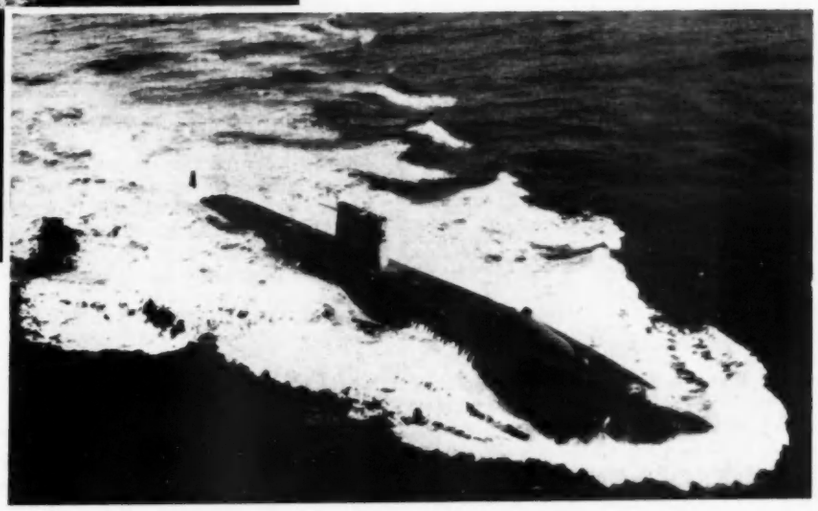
H.M.S. " Finwhale," the sixth submarine of the " Porpoise " class ABOVE, was built by Cammell Laird and Co. (Shipbuilders and Engineers), Ltd. She has a surface displacement of 2000 tons, with an overall length of 295ft 3in and a beam of 26ft 6in, and is armed with eight 21in torpedo tubes, six in the bow and two in the stern. A high underwater speed and long endurance are claimed.



LEFT " 958," new Russian " Z " class submarine of the large ocean-going type, the general appearance of which is very streamlined with a complete row of rapid flooding holes along the casing. Displacement of 1900 tons on the surface and 2200 tons submerged ; overall length 290ft ; beam 26ft. Armament eight 21in torpedo tubes, six forward and two aft ; she carries twenty-four torpedoes. Diesel-electric propulsion, three screws, 10,000 b.h.p. giving a speed of 20 knots on the surface and electric motors of 3500 h.p. equal to a speed of 15 knots submerged. Radius 26,000 miles, complement seventy officers and men. Some units of the " Z " class are reported to mount two 57mm guns in a twin turret before the conning tower and a twin 25mm anti-aircraft gun on the conning tower, and some are reported to be equipped with guided missiles. Others are oilers, and some have a mine carrying capacity alternative to torpedo capacity (forty mines or twenty torpedoes).



U.S.S. " Patrick Henry " BOTTOM LEFT, the first of four nuclear powered fleet ballistic missile submarines completed in 1960, closely following the prototype " George Washington " completed on the last day of 1959. Displacement 5600 tons standard and 6700 tons submerged ; length 382ft ; beam 32ft. She carries sixteen " Polaris " missiles (28ft long, 50in diameter, 15 tons weight, with nuclear warheads, and a range of 1200 miles) capable of being launched while surfaced or submerged, arranged vertical in double rows along the after deck abaft the " sail " (conning tower fin). She also has four 21in torpedo tubes forward. Her propelling machinery comprises one Westinghouse nuclear reactor and General Electric geared turbines. She has two complete crews, each of ten officers and ninety men, relieving each other at three-monthly intervals. She was built in less than two years by the Electric Boat Division of the General Dynamics Corporation, Groton, Connecticut, and commissioned on April 9, 1960. She has auxiliary diesels and batteries, both of which can be used for emergency propulsion.



U.S.S. " Halibut " RIGHT, the first nuclear powered guided missile submarine, commissioned early in 1960. Built by Mare Island Naval Shipyard, California, this submarine was originally designed as a diesel propelled ship but it was subsequently announced that she would be nuclear powered instead of having conventional propulsion. She is the first submarine ever designed from the keel up as a guided missile carrier. She is fitted to handle " Regulus " surface-to-surface missiles. Her hull was designed primarily to provide a stable launching platform rather than for speed or manoeuvrability. With a displacement of 3555 tons standard and 5000 tons submerged she has a length of 350ft and a beam of 29ft. Her main machinery comprises a Westinghouse water-cooled nuclear reactor and Westinghouse geared turbines.

The last conventionally powered U.S. submarine, " Blueback," was also completed in 1960. All subsequent U.S. submarines will be nuclear powered. The nuclear powered attack submarine " Scorpion " was completed in 1960, bringing the number of nuclear powered submarines in commission up to fourteen.

The Contribution of Metallurgy to Electric Power Generation

By L. ROTHERHAM, M.Sc., F.Inst.P., F.I.M.*

The thirteenth Hatfield Memorial Lecture of the Iron and Steel Institute was given in London on November 29 by Mr. L. Rotherham. In his introductory remarks Mr. Rotherham emphasised the need for close collaboration between metallurgists and design engineers in the electricity supply industry : this need was paramount to-day, when great advances were being made both in conventional and nuclear generation plant and when the selection of materials for high duty was of the utmost importance. The major part of the lecture† is reproduced below.

Changing Design Pattern

THE changes in the design of power stations which have been apparent in post-war years have been dictated by economic factors. Steam temperature and pressures have been raised and the size of units has been increased. The same tendency existed before the war but has become accelerated in recent years.

Fig. 1 has been drawn to show the size and steam conditions for typical stations commissioned at different times over the last forty years and including new stations which will be coming into operation in the next five years. A logarithmic scale has to be used to cover an increase in size of over thirty to one. Steam conditions have been increased from 650 deg. Fah. (344 deg. Cent.) and 250 lb per square inch to the current level of 1050 deg. Fah. (566 deg. Cent.) and 2350 lb per square inch, and we can see this increasing still further to 1100 deg. Fah. (593 deg. Cent.) and 3500 lb per square inch by 1965.

In this process of technological development progress has been by discontinuous steps rather than by an obviously continuous process. For example, in the immediate post-war years a halt was called to further development so that a relatively standard type of boiler and turbo-alternator could be installed quickly to meet the deficiency in plant caused by war-time conditions. These were mainly 60MW units of a good level of efficiency, operating with steam temperatures and pressures of 900 deg. Fah. (482 deg. Cent.) and 900 lb per square inch.

Although these steps will tend to exist in future there is no indication that the upward trend in temperature will not continue for many years to come. The effect of this trend is to reduce the operating cost of a station by increasing the thermal efficiency but it is often overlooked that at the same time the capital cost for a given capacity may be increased. In a recent paper[1] with my colleagues Hinton and Brown this problem has been examined in general terms and assuming a fixed size of set of 275MW the result shown in Fig. 2 was obtained. It is expected, therefore, that the increase in thermal efficiency for a particular set size will only be gained at a higher capital cost.

At the present time, and for a set size of 275MW, low thermal efficiencies would not be acceptable and it will be seen that a more complicated thermodynamic cycle using

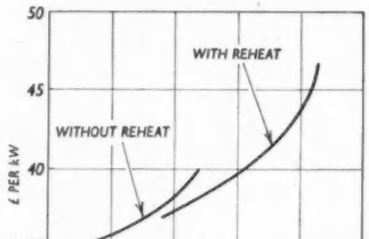


Fig. 2—Coal-fired plant. Variation in costs with steam conditions

reheat is worthwhile. The exact efficiency worth striving for depends, however, on the balance between capital costs and operating costs for new stations and it is easy to see that a substantial increase in fuel costs would justify a modest increase in capital charges to give increased thermal efficiency.

Fortunately, the increase in capital cost due to increased operating temperatures can be more than offset by the economies which can be achieved by increasing the size of sets and it is possible therefore to draw a series of curves similar to those of Fig. 2 for different sizes of set which show the same trend for each size of set but with the larger sets always the cheaper. If we assume that certain sizes could be constructed at different times in the future and also that fuel costs can be expected to rise only slowly then we can forecast the probable economic design points for future stations.

This is illustrated in Fig. 3 taken from the paper by Hinton, Brown and Rotherham already referred to. The probable load factor can be assessed and will lie in the region of 50 per cent throughout the whole life of the plant so that we can obtain from such a curve a fairly clear idea of the type of plant we should plan to install over the next fifteen years.

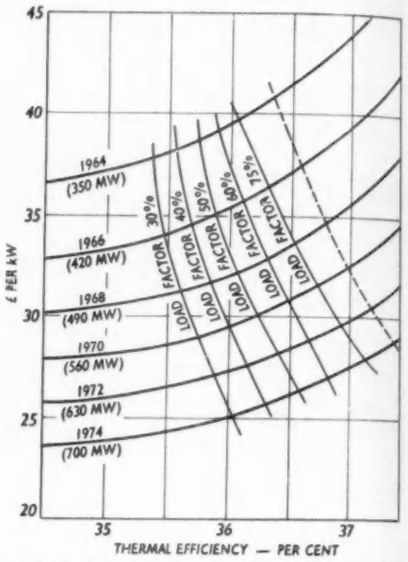


Fig. 3—Coal-fired plant. Probable economic design points for future plant at various load factors

For comparison with these figures it is perhaps worth noting that in 1959–60 a station commissioned in the previous year achieved a thermal efficiency in excess of 34 per cent. Obviously we believe that a 350MW set installed to operate from 1964 onwards will give better than 35½ per cent thermal efficiency, an increase of 1 to 1½ per cent in six years. A further increase of about ¼ per cent which the figure would require in set sizes of about 600MW capacity seems a reasonable target to aim for between 1965 and 1970. Obviously the object of further research and development would be to do this or even better for the capital cost indicated.

The net cost of power plant is tending downwards due mainly to the economies made when the size of the unit is increased. In fact the larger sizes of unit require less metal per kilowatt of capacity than do the smaller. This is indicated by Table I which gives the size of rotor forgings for alternators of different capacity. It will be seen that the size of the rotor shaft does not increase *pro rata* with the capacity although in the most recent sizes they are becoming quite large forgings. There is obviously a point where increasing size could take the forging beyond the capacity of existing manufacturing plant and, since only a small number of these large units are needed each year, it might be uneconomical for the forgemaster to introduce new plant. Until this happens, however, it is substantially true that

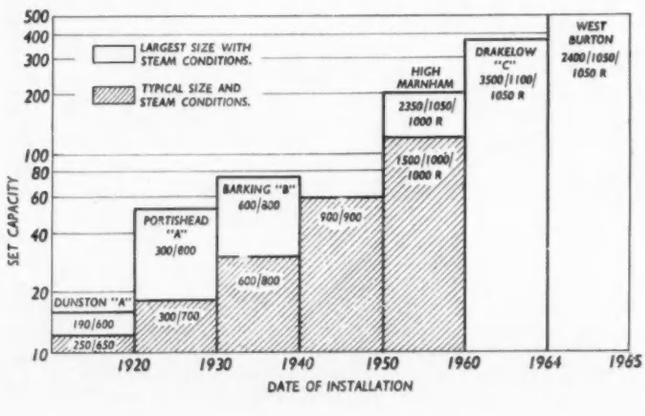


Fig. 1—Size (MW) and steam conditions for typical stations commissioned during the past forty years

* Member for Research, Central Electricity Generating Board.
† The lecture will be published in full in the *Journal of the Iron and Steel Institute*, February, 1961.

TABLE I.—*Alternators*

Station	Commissioning date	Output, MWI	Rotor: Core, length, in	Rotor: Core, diameter, in	Rotor: Core Material, Y.P. and U.T.S., tons per square inch	Rotor: Weight (including shaft tons)	End Rings: Material, Y.P. and U.T.S., tons per square inch
Leicester L.P.	1929	25	120	35	Carbon steel 20/40	21	Magnetic Cr–Mo steel, 58/70
Littlebrook "A"	1939	30	107	34	Grade 2 Carbon steel 20/40	16	Austenitic steel, cold worked, 50/60
Poole...	1951	50	165	37	Carbon steel with 5 per cent Mo 22/40	30	Austenitic steel, cold worked on a mandrel, 45/52
High Marnham	1959	200	180	40	Cr–Mo steel 33/43	40	Austenitic Mn–Cr steel 57/67 — Water quenched, cold worked by the wedge expansion method
Thorpe Marsh...	1963	550 (2×275)	—	—	3 per cent Cr–Mo–V 33/43	56 per m/c	Austenitic steel
Drakelow "C"	1964	375	—	—	Cro–Mo steel 33/43	58	Austenitic Mn–Cr steel 57/67

TABLE II.—*Boilers*

Station	Commissioning date	Boiler capacity lb/hour	Steam conditions: Pressure, lb/in²	Steam conditions: Temperature, deg. Fah.	Total weight of pressure parts, tons	Weight of alloy steel in pressure parts	Weight of alloy steel as percentage of total weight of pressure parts
Leicester L.P.	1930	120,000	350	750	140	Nil	—
Littlebrook "A"	1940	255,000	625	825	210	Nil	—
Poole...	1950	340,000	950	940	337	31	9
High Marnham	1959	1,400,000	2450	1060 1005R	1796	458	26
Thorpe Marsh...	1963	3,900,000	2300	1050 1050R	3577	1157	32
Drakelow "C"	1964	2,500,000	3500	1100 1050R	1708	908	53

a single large forging will be cheaper than many smaller ones.

We have seen from the curves that although increasing size is reducing capital costs, increasing efficiency tends to raise them. The reason for this is that as the temperature and pressure of the steam is increased new materials have to be introduced. This is illustrated in Table II which gives data for actual boiler installations. The important components are the pressure parts, and it can be seen that the proportion of alloy steel to carbon steel has increased from zero to well over 50 per cent and furthermore the complexity of the alloy steel has increased correspondingly. For instance, in stations operating at a steam temperature of 1000 deg. Fah. (538 deg. Cent.) or even 1050 deg. Fah (566 deg. Cent.) low alloy steels of the 2¼ per cent Cr.Mo. type might be permissible, but it is difficult to see how temperatures much in excess of this will be achieved without the use of austenitic steels in the high-temperature boiler parts, the steam piping and to a smaller extent in the high-pressure turbine. This alone will introduce some very interesting metallurgical problems.

Before leaving the question of the changing pattern of design it is possibly worth noting that the methods of designing pressure vessels and other components operating under creep conditions have changed with the passage of time and this also affects the material requirements and metallurgical development. Historically, it is true to say that prior to about 1930 various formulae were available for the design of components largely to meet the requirements of the insurance bodies or to give a good face to a Board of Trade enquiry in the case of accident. This was essentially an extension of design theory based on elasticity rather than plasticity and the Hatfield Time Yield[2] and the Barr-Bardgett type of test[3] were attempts to replace the proof stress of elastic theory by a stress which included a creep component. They became largely outmoded by the studies of R. W. Bailey[4] but, whereas he provided a much more satisfactory design theory, it did not have adequate support in experimental data and for many years the Time-Yield and Barr-Bardgett data had to be used because no better data was available. Even to-day only inadequate design stress test data is available and the extension of creep testing facilities at the Electrical Research Association which has been arranged co-operatively between the electrical industry, the steel industry, the boilermakers and pipemakers is long overdue. This is only one field where the national effort could be strengthened and where more work is necessary.

As the technique of design becomes more precise we shall need to impose greater care on the reproducibility and uniformity of materials and fabrication methods so that the great advantages of precise design can be obtained. We ought to proceed not by learning from our failures but by understanding of our techniques and our materials. This will need a great deal of study and development.

Finally, there is at present some argument on the basis for the selection of design stresses for pressure vessels. On the whole, British methods are conservative although, in the range where creep is a dominant factor, higher stresses are permitted than are customary in, for example, German practice. Conversely, German methods permit higher stresses at low temperatures since they are prepared to adopt a yield stress criterion against British use of an ultimate tensile stress criterion. The present effort devoted to creep testing in Germany will, in my opinion, lead them to accept stress levels comparable with the British and we should be wise to look at the lower temperature range to see if we could accept the higher stresses current in German practice. This would lead to the two design codes coming closer to one another but at higher stress levels than at present and once again this emphasises the need for greater care and a closer collaboration between the metallurgist and the design engineer.

Material Requirements

A brief summary of the design trends would be to say that future requirements will need a continuation of the developments we have seen in the past. These have been seen to be a use of materials in larger sizes and operating under conditions which approach more closely to their limits of capability. In the case of power plant this is sensible. There is no doubt that plant has been built in the past with an expected operating life of 100,000 hours when in fact two or three times that life might have been a more reasonable prediction of the true life. With a progressive trend in design this is uneconomical and it is better to design closely to the expected life with a slight chance that it will fall below 100,000 hours to, say, 70,000 to 80,000 hours, since in the later part of the life of the plant it is relatively uneconomical to operate compared with newly installed equipment.

In the past whatever the design criteria adopted, the metallurgical industries have generally been able to meet the engineering need and in part this has been due to the fact that other requirements, for example, in the chemical industry and in gas turbines, have imposed higher temperature requirements than those of the supply industry.

Before 1934 the sets installed were small and operating at low temperatures. The Generating Board still owns 387 generating sets over twenty-five years of age, all with steam temperatures below 900 deg. Fah., and of these only four have a capacity exceeding 60MW, whereas in the year ending March 31, 1960, twenty-eight new turbo-generators were installed and except for one unusual case all exceeded 60MW capacity and the largest set at present running is 200MW. In only the one exceptional case was the steam temperature below 900 deg. Fah. (482 deg. Cent.) and the highest temperature was 1050 deg. Fah. (566 deg. Cent.).

The smaller sets operate at lower stresses and temperatures and it is a fair statement to say that prior to 1934 carbon steels could meet all the needs. These steels are limited in their high temperature use by creep and for reasonable stress levels can be regarded as unserviceable at temperatures in excess of 850 deg. Fah. (454 deg. Cent.). Even in 1935 R. W. Bailey (*loc. cit.*) pointed out the improved properties of 0·5 per cent molybdenum steel showed a considerable improvement over carbon steel which can be assessed as giving a service temperature of 950 deg. Fah. (510 deg. Cent.) for the same stress levels as prevail in carbon steel at 850 deg. Fah. (454 deg. Cent.). A material with these properties might be regarded as suitable for service in the power stations of even the post-war era which, as I have said, included many stations operating at only 900 deg. Fah. (482 deg. Cent.). However, as is well known, it proved to have a grave defect in having a very low ductility under creep conditions which lead in certain cases to premature failure.

Alternative materials were available when the limitations of 0·5 per cent Mo. steel were revealed and in particular molybdenum-vanadium and chromium-molybdenum steels have been used extensively. Perhaps the extended studies of Glen[5] of these materials should be noted here since they give a reasonable basis for comparison between experience and laboratory tests, which is important.

His work appeared in print after the war but an early use of chromium-molybdenum steel containing 0·8 per cent Cr. and 0·5 per cent Mo. was in the Brimsdown "A" power station commissioned in 1938, with the very advanced steam conditions for that period of 1900 lb per square inch and 930 deg. Fah. (499 deg. Cent.) at the turbine stop valve. We have recently been able to make a detailed study of the history of these materials after twenty years' service and can assess the deterioration in properties and the limiting service conditions with greater accuracy than was possible from laboratory tests alone.

History of Materials at Brimsdown "A"

The history of the two boilers in question is that they were commissioned in 1938 and no failures of superheater tubes were recorded in the first eleven years of operation. In 1950, after about 57,000 hours of running a tube failure was recorded on No. 2 boiler, and failures were recorded on this boiler each year to 1959 when it had reached 99,000 hours running time. The first failure listed on No. 1 boiler was in 1952 after 68,000 hours running and again failures were observed in each year until 1959. This experience is shown in Table III.

Table III—*History of Superheater Tube Failures at Brimsdown.*

Year	Total running hours		Number of tube failures	
	No. 1 boiler	No. 2 boiler	No. 1 boiler	No. 2 boiler
1938...	Boilers commissioned			
	No failures in the period 1938–49 inclusive			
1949...	51,520	51,441	—	—
1950...	57,090	57,367	—	1
1951...	62,316	62,623	—	2
1952...	68,358	68,766	1	4
1953...	74,341	74,729	1	3
1954...	79,910	80,017	4	6
1955...	85,602	85,308	5	8
1956...	90,136	89,450	1	5
1957...	94,707	93,766	3	4
1958...	97,043	96,994	1	5
1959...	99,796	99,146	2	1

The failures observed in the period 1955–57 were sufficiently troublesome to make it worthwhile to renew the convection superheater and steam outlet of both boilers, and this renewal was made in 1959. This provided an opportunity for an extensive study to be made into the service conditions and the change in properties of the steel. This study included the following items :

(*a*) Measurement of metal temperatures during the last six months of superheater service.

(*b*) Microstructural examination and stress rupture tests on samples removed in 1958 prior to the last six months' service.

(*c*) Microstructural examination of many tubes and header samples taken on dismantling.

(*d*) Further tests of creep properties and stress-rupture properties on samples selected on the basis of structural changes determined under (*c*).

There is no need to describe the design of the superheater in detail here but the convection superheater with which we are concerned can be regarded as consisting of two horizontal banks of tubes which for convenience we call the upper and lower tube banks. Thermocouples were inserted into the tube banks and the superheater headers of No. 2 boiler and observations continued for about six months in early 1959.

The highest temperatures recorded are shown in Table IV and from this it will be seen that throughout the tubes temperatures in excess of the design temperature were recorded. Perhaps equally important as the temperature is the time spent in the higher ranges and in this connection it is worth noting that the lower tube bank operated mainly at or near the design temperature or lower, with only occasional high temperature readings but on the upper tube bank readings showed metal temperatures above the design temperature of 930 deg. Fah. (499 deg. Cent.) for over 70 per cent of the time of observation and even above 1050 deg. Fah. (566 deg. Cent.) for more than 5 per cent of the time. Five per cent of 99,000 hours is nearly 5000 hours.

Table IV—*Maximum Temperatures Recorded.*

Position	Maximum temperature	
	Degrees Centigrade	Degrees Fahrenheit
Bottom of lower bank	548	1018
Bottom of upper bank	585	1085
Top of upper bank...	589	1092

The temperature variations from point to point in the superheater are considerable as are the times spent at the higher temperatures but the results obtained can be no more than indicative of the probable conditions prevailing in the boilers. Observations show that the metal temperature varied according to whether the thermocouple on a particular tube was in a position facing the furnace gas stream or sheltered from it and considerable variation in microstructure was observed along the length of a single tube. Whether this should be attributed to slight variations in temperatures over long times or whether fluctuations in temperature with high temperature peaks for short times would have bigger effects is uncertain on the data available from this study alone. What is more certain is that the change in microstructure can be correlated with a change in stress-rupture properties of the material.

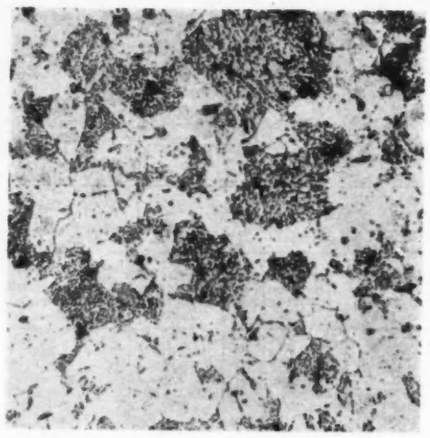


Fig. 4—Microstructure of the underside of the tube TT8

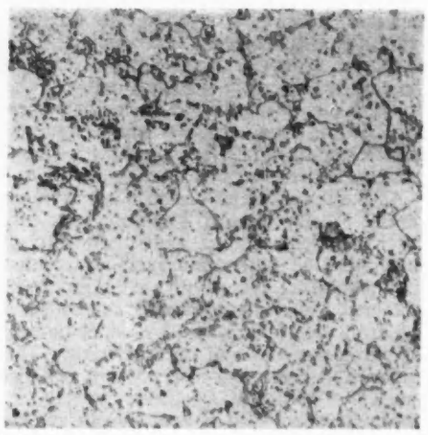


Fig. 5—Microstructure of the underside of the tube BT9

Two typical microstructures of tubes after service are shown in Figs. 4 and 5. The first of these refers to a tube identified by the number TT8 and this was a top tube in the upper bank and was in service for 97,000 hours. The second, identified as BT9 is from a bottom element in the upper tube bank after the same service life. In both cases the service temperature could only be inferred from the data obtained which would suggest that the bottom element BT9 was subjected to greater fluctuation in temperature and a longer period at temperatures both in excess of 1050 deg. Fah. (566 deg. Cent.) and below 950 deg. Fah. (510 deg. Cent.) than the top element TT8.

This is consistent with the differences in microstructure. There is undoubted spherodisation of the pearlite to be seen in Fig. 4, but this is less pronounced than in Fig. 5. In both cases changes in composition of the carbides are to be seen and in the bottom tube element some recrystallisation of the ferrite had occurred.

The change in strength properties associated with the change in microstructure is indicated in Fig. 6. For comparison data is given on a new tube and on a replacement tube BB9 which was tested after 7000 hours' service. The position of this tube was in the bottom lower tube bank and the microstructure showed spherodisation proceeding on the lower side of the tube but not visible on the top of the tube. The results shown relate to spherodised material from this tube and the data seems to be fairly conclusive.

We can conclude that the deterioration in properties is associated with the change in microstructure and that some part of the change in structure occurs in an early part of the service life. In exceptionally severe conditions more progressive deterioration will occur giving a further reduction in rupture strength. The question we now have to answer is whether the changes are important.

This is answered by considering the stress levels involved. The nominal value of the average stress in the tube, calculated on the thin cylinder formula, is 3·8 tons per square inch. Fig. 6 shows that at 4 tons per square inch, in the acutely spherodised state, failure can occur in less than 6000 hours at 1050 deg. Fah. (566 deg. Cent.). To make the matter more conclusive we can also record that the thinning of the tube wall by external corrosion

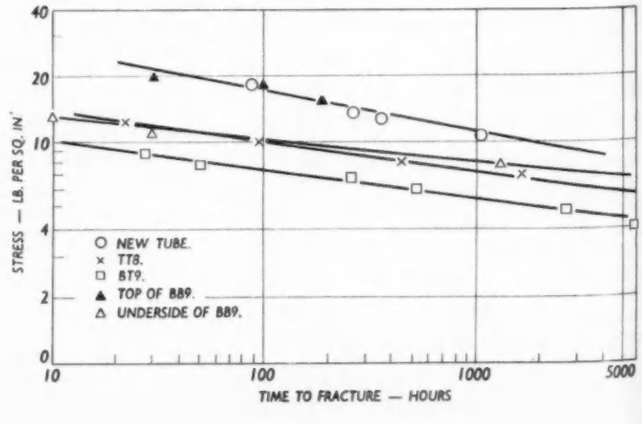


Fig. 6—Relationship between stress and time to fracture in tests on tubes TT8, BT9 and BB9 at 1050 deg. Fah.

amounted to as much as 12 per cent, giving a nominal stress of more than 4 tons per square inch, while the temperature records show that for the severely spherodised tube it had probably spent more than 5 per cent of its life (i.e. more than 5000 hours) at temperatures in excess of 1050 deg. Fah. (566 deg. Cent.).

The evidence therefore shows that these failures were due to a combination of circumstances ; mainly corrosion, temperature fluctuation and excessive temperatures and if these could be minimised, good service could be expected from the Cr.Mo. steel used in the Brimsdown boilers.

Similar investigations have been made on other materials, of course, and further work will continue at Brimsdown on the replacement materials in the superheater.

The advantages to be gained by the use of later steels such as 2¼ per cent Cr.Mo. or ½ per cent Mo.V or even Cr.Mo.V types, in part, can be attributed to a change in performance due to better rupture strength, better corrosion resistance or, most likely, to greater stability of properties and structure compared with simpler alloys. On the whole, most service needs can be met for temperatures below 1050 deg. Fah. (566 deg. Cent.) using these low alloy materials but clearly oxidation resistance alone, is beginning to rule them out for any higher temperatures and more highly alloyed steels will be necessary in future.

Future Needs

We have already seen that, in general, the power plant needs have been met by materials which were available before the design requirement arose. Increasingly we can expect that the materials developed for use in high temperature machines such as gas turbines will find application, in steam power plants. With this in mind, certain power stations have incorporated austenitic steels in, for example, the superheaters and steam pipes although the service temperatures of 1050 deg. Fah. (566 deg. Cent.) could equally well have been met by ferritic steels. This has proved to be a valuable experiment since certain difficulties in the use of austenitic steel have been exposed.

The steel initially chosen for installation in three power stations in this country was the composition 18 per cent Cr. 12 per cent Ni. 1 per cent Nb which is well known to combine good high-temperature creep and corrosion resistance. It has been extensively used in pressure vessels for the chemical and similar industries and a great deal of fabricating experience is available from the nuclear chemical plants and elsewhere. The installation of this material for power station use was begun in 1954 and continued until 1959. Some troubles were experienced as early as December 1955 when routine inspection of butt welded joints on a main steam line revealed cracks. A complete inspection on all the main steam lines using this material was instituted and nine joints in all were found to be cracked. A programme of annual inspection of steam pipe joints was introduced and further cracks have since been revealed. The incidence of cracking has been reduced by better fabrication methods but it is not yet completely eliminated.

Later experience in the superheaters has confirmed that cracking can occur in the 18/12/1Nb steel. Cracks were observed in superheater stub tube welds in 1957 and 1958 and some cracking has been produced even before the superheater components have been effectively placed in service. On the other hand satisfactory steaming for periods in excess of 20,000 hours has been obtained in other cases so that even in material which may have cracked or been near to cracking, as fabricated, it is possible that it was not far from being satisfactory for use.

A very careful study of the type of failure experienced has been made[6] and it has been shown that the cracks are confined to the heat-affected zone and do not occur in the weld metal or in the unaffected parent metal. Both in the laboratories of the Central Electricity Generating Board and elsewhere evidence has been obtained to show that in the region of the cracks the microstructural changes indicate that niobium carbide may be dissolved during welding and then precipitated during cooling or in post-weld heat treatment. A critical dispersion of the precipitate may leave a band of material of low ductility near the weld metal which may crack at low strains arising from service or even from the relief of thermal stresses.

A knowledge of the mechanism of the process has led to revised fabrication methods which are likely to give satisfactory performance in service but it must be admitted that the 18/12/1Nb steel although resistant to creep does not have a high ductility at fracture in long periods and alternative materials have been sought.

One such material which has been recommended in the U.S.A. is the austenitic steel containing 17 per cent Cr. 10 per cent Ni and 2 per cent Mo. This has a creep resistance comparable with that of 18/12/1Nb and apparently a considerably better ductility but there is little operational experience in power plant in this country to show that it will be completely satisfactory. If it is, then it is probable that we can assume that materials are available which will permit steam temperatures to be raised at least to 1150 deg. Fah. (621 deg. Cent.) and perhaps to 1200 deg. Fah. (649 deg. Cent.) without too much difficulty.

I think that this is a case where we can see clearly the way in which a design need can be met and it may be as near to a successful solution to the problem as the use of Cr.Mo. steel at Brimsdown was. However the failures at Brimsdown were due to a combination of circumstances and the near success was largely fortuitous. I do not think we can take such risks with equanimity, and more elaborate assessment of materials before selection is relatively inexpensive compared with the economic consequences of a wrong decision. This consideration is not only confined to heavy and expensive items of plant but applies to small items where the design requires the material to perform a high duty. Many additional examples could be quoted.

Conclusions

Although the examples used for illustration are merely related to boiler and steam pipe problems, it can be assumed that the same general considerations apply to materials problems in the turbo-alternator and, in a different way to transformers, switchgear and other components. In every case the design of components is becoming more precise and to meet the designers' needs, a more accurate knowledge of the materials of construction is required. It seems inevitable that the trend of design to give plant of higher thermal efficiencies will continue and for some time yet we can expect an increase in size in individual units of plant. Both these factors will tend to impose continuing metallurgical problems.

We shall not, in future, be able to risk using new materials in service until extensive laboratory and even pilot plant studies have shown the risk is slight. To put this in perspective we can note that a 500MW unit boiler and turbo-generator installation will have a capital cost of about £20,000,000 and the units of production lost in a single day of outage might be sold for say £50,000. We ought, therefore, to be giving much greater attention to devising the materials which will be necessary for the designs evolving for plant to be ordered in future years and in establishing procedures which will indicate that the materials selected will be satisfactory. This is a question which will require the collaboration of the metallurgical industries as well as the electrical manufacturers, the boilermakers and the electricity generating industry. Fortunately there is already a good spirit of collaboration and in all the industries there is a tradition of close association between designers and metallurgists.

In passing we should note the important part to be played by the plant operators. There is a strong probability that, with closer design methods and materials stretched to the limit of their capacity, both of which are necessary for maximum economy, the operators will have to maintain even closer control of very large and complicated installations. For this purpose they will need to be supported by the best modern aids and research on this is, of course, proceeding all the time.

Personally, I have no doubt that we shall continue on the path now being followed. We should succeed in increasing the thermal efficiency of our stations and by the trend to increased size of unit this should be achieved without any substantial increase in capital cost and indeed probably at lower capital cost. Although the complicated and costly but highly efficient unit of the future will need close operating control this also should be achieved. This is our hope since it is largely the definition of an efficient industry.

References

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[2] Hatfield, W. H., "Permanence of Dimensions under Stress at Elevated Temperatures," *Journal of the Iron and Steel Institute*, Vol. 122, pages 215–31, 1930.

[3] Barr, W., and Bardgett, W. E., "An Accelerated Test for the Determination of the Limiting Creep Stress of Metals, *Proc. I.Mech.E.*, Vol. 122, pages 285–97, 1932.

[4] Bailey, R. W., *Proc. I.Mech.E.*, Vol. 131, page 131, 1935.

[5] Glen, J., *Journal of the Iron and Steel Institute*, Vol. 158, page 37, 1948.

[6] Asbury, Mitchell and Toft, *Brit. Welding Journal*, Vol. 7, page 667, 1960.

Nuclear Translation Pool

The European Atomic Energy Community (Euratom), the United Kingdom Atomic Energy Authority and the United States Atomic Energy Commission have agreed to pool their efforts to collect and disseminate information concerning translations of nuclear literature, especially from such languages unfamiliar to Western readers as Russian and Japanese. A central information office "Transatom" has therefore been established at Euratom's Brussels headquarters. It will function in two ways : first, by publishing from December, 1960, onwards a monthly *Transatom Bulletin*, which will list existing translations recently reported to the Brussels office as well as new translations planned by international or national institutions and private firms in the European Community, the United States, the United Kingdom and in other countries.

Secondly, all data relating to translations, including those made before the establishment of Transatom, are to be collected and recorded in a master file at Brussels. Copies of this card file have been offered to appropriate institutions in countries with an interest in the nuclear field.

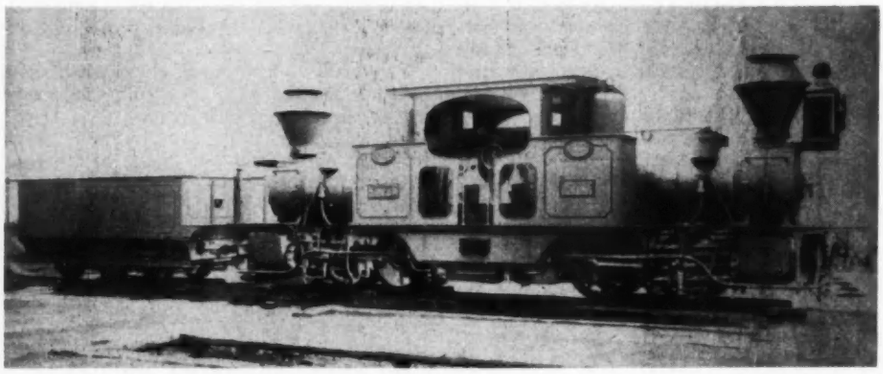
Contacts have been established in order to avoid duplication of work when the European translation centre, to be established at Delft, is set up. The scope of this institution is much wider, as it will cover all scientific and technical material in the field of the exact sciences.

LETTERS AND LITERATURE

Letters to the Editor

THE FAIRLIE LOCOMOTIVE

SIR,—In the second instalment of my article on the Fairlie Locomotive published in the issue of THE ENGINEER for March 4, page 384, some particulars were given of seventeen 0–4–4–0 locomotives built by the Avonside Engine Company of Bristol in 1880–81 for the metre gauge lines of the North Western State Railway of India and for Burma (Works Nos. 1245–1278). Through the courtesy of Mr. A. G. W. Garraway, General Manager of The Festiniog Railway, it is now possible to illustrate No. 1278 of this class, and the particular interest here



is that the locomotive is shown coupled to a tender, and as there is water piping leading to both ends, the tender is obviously intended to be used at either end as required. This is the first instance of a Tender–Fairlie known to the writer.

The original is a large sepia print and appears to be an official photograph taken at the Avon Street works of The Avonside Engine Company.

Incidentally this is one of a collection of Fairlie Locomotive Photographs recently presented to The Festiniog Railway Company by one of Robert Fairlie's descendants, now residing in Hove.

R. A. S. ABBOTT

Oxford,
December 17, 1960.

MILLIONS TO BE SAVED ?

SIR,—The advocates of schemes for turning our railways into roads are evidently quite unmoved by the certainty of appalling increases in the already frightfully high number of road casualties.

A survey, based on police figures tabulated by the Road Research Laboratory, shows that in the first ten months after the opening of the London-Birmingham Motorway (M 1) no less than twenty-one people lost their lives in sixteen accidents. *Pro rata* this would be twenty-five in a year for a 75 mile stretch of road.

Brigadier T. I. Lloyd is anxious to convert over 20,000 miles of railway to road, so we must expect over 5,000 additional deaths, even if the most rigorous precautions are taken, as on the M1. Contrast this with our present security on the railways. During the whole of 1959 only one train passenger met his death, but there were 161 fatal accidents to staff, making a total of 162 deaths.

I should like an answer to two queries :

(1) A train passenger can expect to reach Glasgow or Edinburgh from London in seven hours to eight hours at any season of the year. How long will it take by coach or bus ?

(2) I travel from Luton to St. Pancras (30½ miles) by the 7.55 a.m. diesel on five days a week. It is scheduled to reach St. Pancras at 8.27 a.m. with one stop at Harpenden, which station it leaves at 8.2 a.m. making a run of 26 miles in twenty-five minutes, and it is seldom more than two minutes or three minutes late. Does Brigadier Lloyd consider this could be equalled by coach or bus, or even a converted railway, apart from the increased danger to life and limb ?

C. F. COBON, A.M.I.Mech.E.

Luton,
January 4, 1961.

Book Reviews

World Railways. Sixth Edition. Sampson Low's "World Railways," Ltd., 16, Maddox Street, London, W.1. Price 105s.

THIS edition of *World Railways* has been completely revised and re-set. Its contents are divided into four sections, the first two of which deal with the major railway systems. Details are first tabulated country by country, the data including operating and financial statistics as well as particulars of rail weights, couplings and buffers, sleeper material and spacing, and other subjects on which information is useful to industry when tendering. This tabular section is followed by amplified and illustrated particulars of the major lines, in the same order of continents and countries, and summaries of the products of the principal railway equipment manufacturers in the various territories. The combining of railway and manufacturing details country by country in one section is a new feature of this edition. Care has been taken to avoid duplicating illustrations, so that a locomotive does not appear both under the heading of a railway and its builder. There are lapses, however, but on the other hand close observance of the principle sometimes makes a manufacturer's entry look like Hamlet without the Prince of Denmark.

Most countries have provided loading gauge diagrams—another feature of this publication which has helped to establish it as a source of reference for industry. The maps, however, are not consistently useful. They vary from the mass of illegible station names resulting from showing the Chicago, Milwaukee, St. Paul and Pacific system in a space of about 7in to 3¾in, to the Acheson, Topeka and Santa Fe map which goes to the other extreme in omitting the names of many terminal and junction points. A publication such as this is naturally dependent on the material with which it is supplied, but the possibility of redrawing and editing in cases such as this should be considered. Useful additions to the text this year are details of economic conditions and trends in the principal countries.

The two final sections follow similar lines to the above and are concerned with underground railways and rail traction diesel engines. The interpretation of "underground" is broad, since the Copenhagen suburban system finds a place on the strength of 1 mile in tunnel between two city stations. Brief mention is also made of lines with tunnel sections through which tramway vehicles operate. Although this section is relatively short, and the user familiar with the book can turn rapidly to the line required, it would save time for others if separate administrations operating underground lines were included in the alphabetical general index of railways.

Absorption. By K. THORMANN. Berlin-Göttingen-Heidelberg : Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3. Price DM.28.50.

THE volume on the technology of absorption by K. Thormann constitutes the sixth in the series *Verfahrenstechnik in Einzeldarstellungen* (editors : J. Spangler and W. Matz). Its aim is to represent the subject in a concise and clear manner for the benefit of engineers and chemists. Starting with a consideration of phase equilibrium between the gaseous components and the solvent, the author proceeds to discuss the transfer mechanisms involved on the basis of the boundary layer concept. Attention is then devoted to the design of counter-flow systems, the absorption of complex mixtures, dissipation of the heat of absorption, solvent regeneration, and absorption with chemically acting solvents. The final chapters are concerned with control problems and questions of economy.

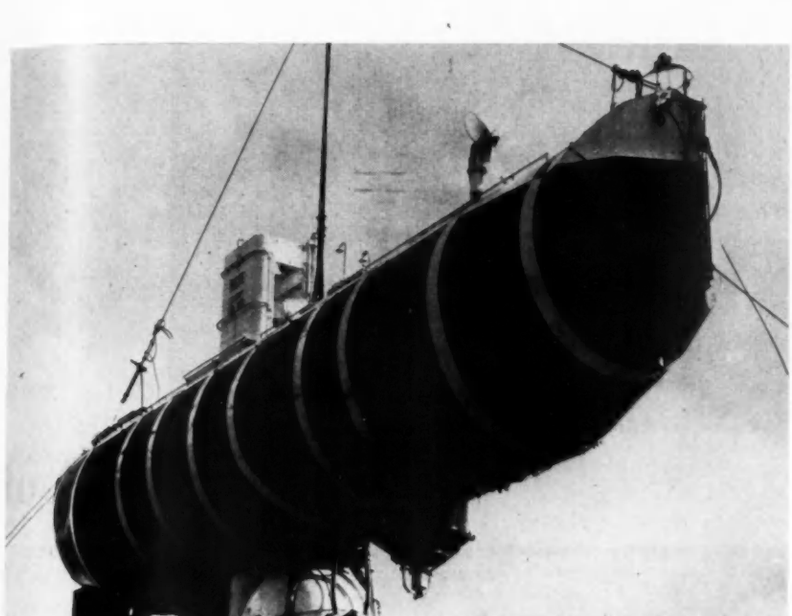
Books Received

Public Relations and Management. By David Finn. Messrs. Chapman and Hall Ltd., 37, Essex Street, London, W.C.2. Price 36s.

Hydro-Electric Power. By Ernest F. Carter. Frederick Muller Ltd., Ludgate House, 110, Fleet Street, London, E.C.4. Price 9s. 6d.

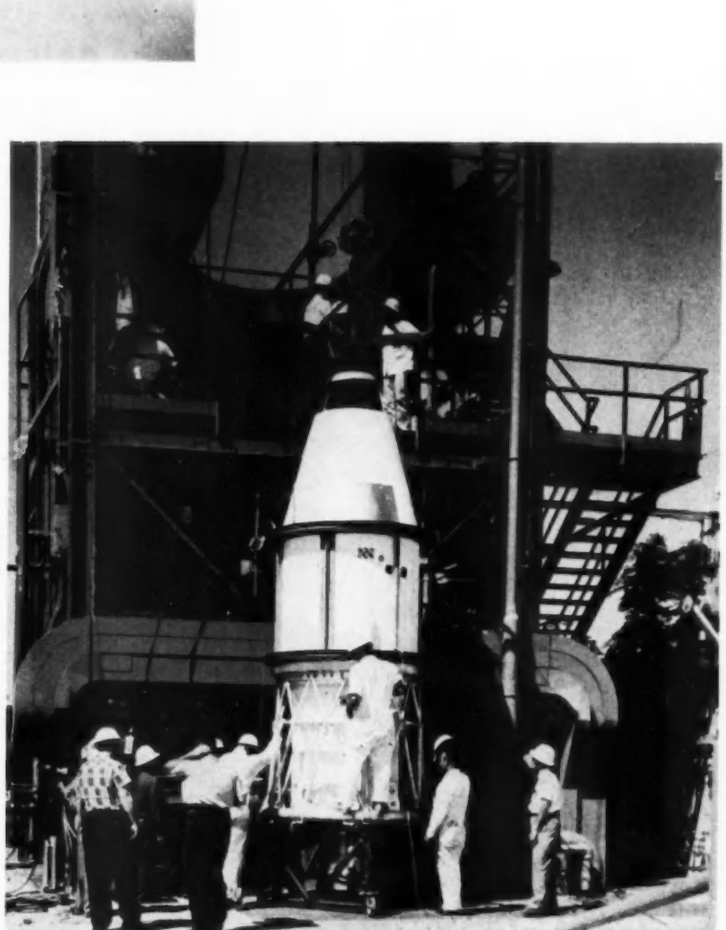
The Uses of Electricity in the Oil Industry. Edited by E. A. Reeves. Ernest Benn Ltd., Bouverie House, Fleet Street, London, E.C.4. Price 50s.

PICTORIAL REVIEW OF 1960



PENETRATION into stranger and more and more forbidding environments has been an exciting adjunct of technical advance throughout the ages ; we continue our review with two outstanding recent illustrations drawn, as it were, from opposite ends of the scale. After preliminary dives to 5668m and 7300m, Jacques Piccard, this time accompanied by Don Walsh of the U.S. Navy, on January 23, reached the deepest known point of the seabed in the Mariana Trench. The craft used for the 10,914m descent was the seven-year-old bathyscaph " Trieste," LEFT, equipped for the occasion with a new pressure gondola made by Krupp. Its principle is that of an " underwater balloon." Invented twenty-five years ago by Professor August Piccard, father of Jacques Piccard, it has a compartmented hull filled with 125 cubic metres of petrol from which is slung a 12-ton steel sphere, 2·18m in diameter and with 120mm thick walls. Buoyancy is increased by jettisoning steel shot and decreased by releasing petrol. The petrol communicates with the sea so that there is no resultant pressure on the hull, while the steel sphere can resist nearly 2200 atmospheres, as shown by tests on a 1 : 20 scale model which was crushed at that pressure. The sphere is built up of three chromium-nickel-molybdenum steel forgings, i.e., a ring and two ends whose conical contact surfaces have their apex at the centre of the sphere. The joints are true to within 0·05mm, and are bonded with " Araldite." The two windows are truncated cones of clear plastics. In the actual dive, a maximum of 1152 kg per square centimetre was registered, corresponding to 43,000 tonnes on the section. An observation of major interest was that of a fish near the bottom, indicating the presence of oxygen and hence of vertical currents. These would render the dumping of radioactive wastes extremely risky.

For many scientific and utilitarian purposes an inert earth satellite is inadequate, and a particularly common demand is that the satellite be stabilised with respect to earth or to the stars, in order to receive or to transmit radiation. A further requirement that has attracted particularly widespread attention is for the satellite to be able to modify its orbit, usually in such a direction as to re-enter the atmosphere. Perhaps the earliest and certainly the best known manoeuvrable satellite is the Lockheed " Agena " so prominent in the " Discoverer " programme of the United States Air Force; one is seen RIGHT at Vandenberg A.F.B. on the shores of the Pacific before being boosted into a polar orbit. The engine of the satellite is a Bell " Hustler," so called since it was designed to power the pod of the B-58 bomber of that name ; it runs on fuming nitric acid and wide-cut kerosene, and can be restarted after a prolonged free fall. When in orbit, the " Agena " is stabilised, and it is of course necessary for it to be oriented with great accuracy before the engine is started to break or modify the orbit. The satellite is capable of attaining an orbit with no larger booster than a Douglas " Thor," and instrumented capsules separated from it were on two occasions last year recovered after re-entry. The " Agena " is essentially a short-lived vehicle, and satellites intended to remain active for long periods would differ in many respects. Power requirements would be drawn from solar radiation, or nuclear reactors for large demands, and attitude adjustment would be effected with rotating masses rather than jets of matter.



Aspects of

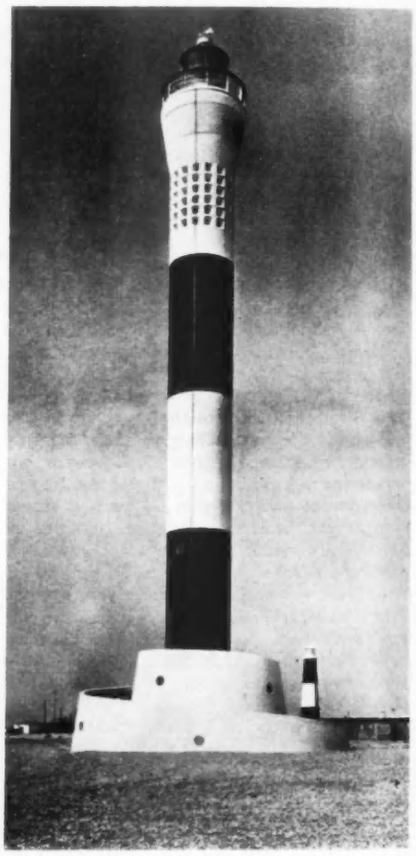
MEHRABAD Airport, ABOVE, is now in the final stages of completion, and is the most modern airport in the Middle East. It is 6 miles west of Teheran at an altitude of 4000ft, and is now in full use by all modern aircraft, including the Boeing 707 and D.C.8.

The main runway which is 9100ft long and 180ft wide, comprises 8in thick reinforced concrete slabs laid on a well graded gravel base. A second main runway has recently been built 12,200ft long and 137ft wide. Provision has been made in the parking apron at the front of the terminal building for the static refuelling of aircraft from hydrant pits connected to a bulk supply manifold by ducts in the apron, thus keeping this area free from fuel tankers with their attendant fire hazards as well as enabling refuelling to be carried out expeditiously.

Full Calvert high and low intensity approach lighting is being installed on the main runway. The air navigational aid equipment provided includes v.h.f. and h.f. radio instrument landing system (I.L.S.) airfield surveillance radar, voice recording equipment and complete teleprinter and message systems.

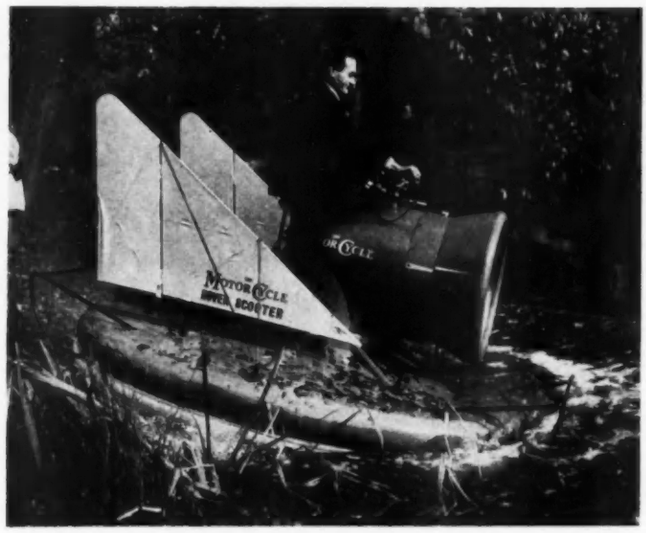
The terminal building covers every possible service required for an international airport of this size. A very extensive air conditioning and heating system is installed in this building in view of the wide temperature range from 30 deg. below freezing in the winter to 110 deg. Fah. in the summer. The power supply is at present provided by a diesel power station comprising four 500kVA sets and 3·3kVA ring main distribution system. The airport will eventually be supplied from the municipal network, when the diesel installation will be kept as a standby. Consulting engineers, Brian Colquhoun and Partners; specialised services, International Air Radio, Ltd.; main contractor, Messrs. Sentab of Sweden.

Dungeness lighthouse, RIGHT, is the first major lighthouse built in this country for over fifty years. It comprises a tower 130ft high built of twenty-one precast concrete rings post-tensioned by vertical cables. The light source is a stationary, flashing Xenon light instead of the usual revolving navigation light. Full description: The Engineer, July 29, 1960, page 206.

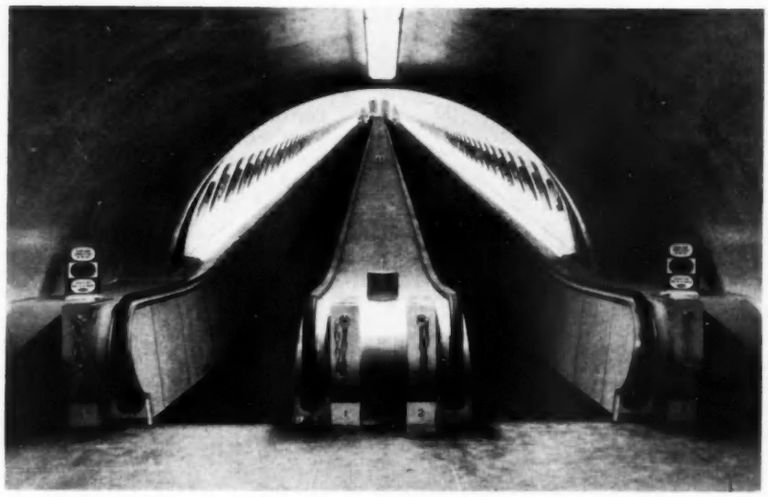


The car park, BELOW, built for Multideck Car Park Developments, Ltd., at Bristol, is in the form of a continuous ramp of even gradient, 1 in 32 on the straight. The overall width of the ramp is 56ft, made up of a 24ft roadway with parking spaces of 16ft on either side. Total capacity is over 500 parking spaces; two lift towers in the central well contain lifts for passengers. The reinforced concrete frames consisting of *in situ* cantilever beams and *in situ* columns are spaced at 16ft centres. The decking has a precast concrete rib and *in situ* concrete topping. The construction of a second "Multidek" car park, with a capacity of 1140 parking spaces, has already started at Lee Circle, Leicester, and it is anticipated that a third at Bath will start soon. Contractor, William Cowlin and Son, Ltd.; consulting engineers, G. C. Mander and Partners. Mr. E. N. Underwood was associated with the Bristol Car Park.

Increasing interest is now being accorded to the ground effect machine, particularly on account of its ability to operate over unprepared surfaces in undeveloped territories. One of the very few that have been displayed to the public in this country is the "Hover Scooter" of Rhoades Incorporated, Pittsburgh, Pennsylvania, which is seen RIGHT entering upon the surface of a lake. Like all the other machines in this country, but not all the United States designs, the "Hover Scooter" creates and contains its pressure cushion with an inwardly inclined jet sheet, but because, uniquely, it generates thrust solely by tilting the "lift" axis, and also because such small ground effect machines are inherently heavy on energy, it also has a flexible curtain to make higher hovering economic for crossing irregular surfaces. It is again unique in that directional control also is obtained without any auxiliary jets; in the annular orifice of the main jet are fitted 116 vanes pivoted about radial axes, and these respond to the handlebars. The air is supplied by a four-bladed fan driven by a 250 c.c. Yamaha two-stroke twin. The hull shape is made by hot working U.S. "Royalite" in an expanded form.



Transport

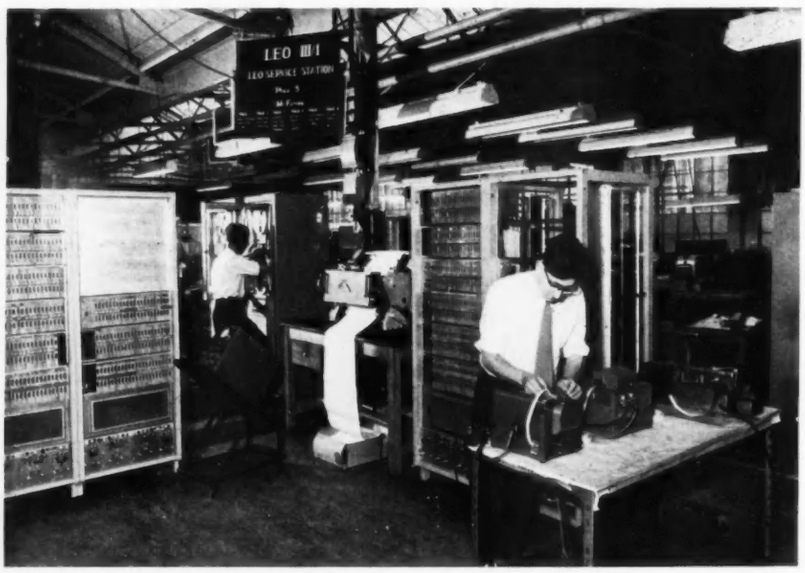


The Waterloo and City underground line of British Railways carries about 40,000 passengers a day—most of them in the morning and evening rush hours. Augmented train services were needed, and, as a result of modernisation, possible at the rush periods, but the means of access to the line at the Bank terminus, a pedestrian subway, was already inadequate for the traffic it had to carry. Passenger movement at this point has been mechanised by the installation of twin Otis Elevator "Trav-o-lators" LEFT—moving platforms about 300ft long—in a specially driven tunnel parallel with the existing passenger subway, and rising at a gradient of 1 in 14 from the underground station to just below street level. Both platforms will run in either direction. Operating at maximum speed (180ft per minute), the theoretical capacity of each "Trav-o-lator" is 16,200 passengers per hour.

Although suspension railways save valuable space at ground level, they have generally proved too noisy and unsightly to be acceptable in cities. The 100km. p. h. prototype at Chateauneuf-sur-Loire in France RIGHT is claimed to have overcome these drawbacks. The cars are suspended from two electric bogies with steel-cord-reinforced pneumatic tyres running inside a box girder track. A pneumatic-hydraulic suspension automatically tilts the cars at the curves and maintains them vertical and at correct platform level independently of the load while in a station.

Computers

Data processing requirements in business and industry are being met by computing installations of increasing versatility. When the "Emidec 1100" computer of E.M.I. Electronics, Ltd., went into service on September 5 at the Nottingham head office of Boots Pure Drug Company, Ltd., it was stated to be the largest single electronic data processing system at work in British business up to that time. The illustration RIGHT shows from left to right one of the two computer cabinets, the six magnetic tape units, the console, two paper tape readers, a punched card reader and, in the centre, the automatic tape punch and monitor printer. This fully transistorised installation began by processing all orders for photographic equipment from 1300 Boots shops, and will gradually take on other classes of goods until it covers all the 60,000 different lines stocked in Boots warehouses. The computer will keep a perpetual inventory of every one of these lines, showing how the stock stands at any moment. A typical "Emidec 1100" installation uses 10,000 transistors, 60,000 ferrite cores and 25,000 diodes. Speed of operation is nearly 500,000 calculations a minute.



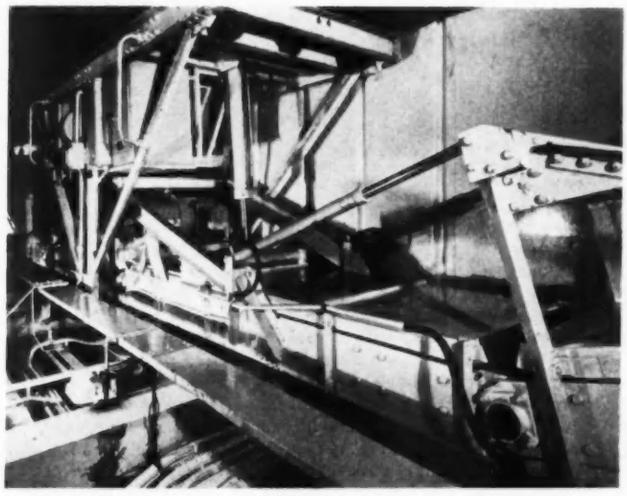
The illustration LEFT shows part of a prototype "Leo III" computer under test at the Acton Works of Leo Computers, Ltd. A characteristic of this data processing device is the microprogramming principle whereby a mathematical operation involving numerous steps may be initiated by a single instruction to one of the planes of magnetic cores forming the programme control. In the illustration the computer cabinet doors have been removed to show the close-spacing of the circuit packages which contributes further to the economy of space realised by the magnetic core storage and the transistor circuitry. On the right are paper tape reader and punch input devices, and in the centre a high-speed printer which operates at 850 lines a minute by means of a printing drum and electronically timed hammers operating on a printing ribbon between the paper and the drum. In the background are two tape transports capable of reading at rates up to 45,000 alpha-numeric characters a second.

We illustrate BELOW parts of the United Kingdom Atomic Energy Authority's computer section at Risley, showing LEFT a "PACE" analogue computer and RIGHT programmers setting up patch panels for the "PACE" computer. The section also contains Ferranti "Mercury" and I.B.M. "704" digital computers, and hand calculating machines for simple problems.

Mechanical Handling Equipment

AMONGST the interesting mechanical handling plants described in our pages during 1960 were installations at Leeds postal sorting office and on two new ships. The mechanised sorting equipment installed in Leeds by Sovex, Ltd., is designed to handle up to 250,000 parcels a week. In this system parcels are delivered in bulk by a conveyor on to glacis behind twelve sorting stations as illustrated ABOVE RIGHT. Each parcel in turn is placed on a trap by the sorter who depresses push-buttons according to a destination code. As each parcel drops through the trap it falls into one of the compartments of a "hopper" train ABOVE LEFT. This hopper train carries the parcel along a line of twenty-four "collecting" belt conveyors and deposits it upon the conveyor appropriate to its destination.

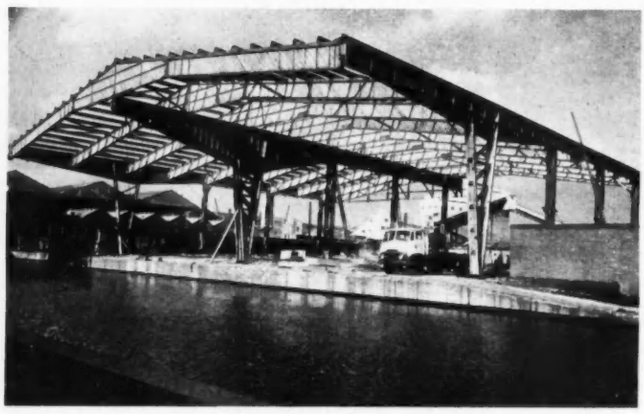
Another Sovex installation was a mechanised baggage handling equipment for S.S. "Oriana" which was described and illustrated in our issue of May 6 last. The illustration RIGHT shows the shipside slat conveyor in its stowed position on the ship. This conveyor has pivoted jibs on which baggage is delivered to the baggage hall from the quayside and it works in conjunction with shipboard conveyors and elevators.

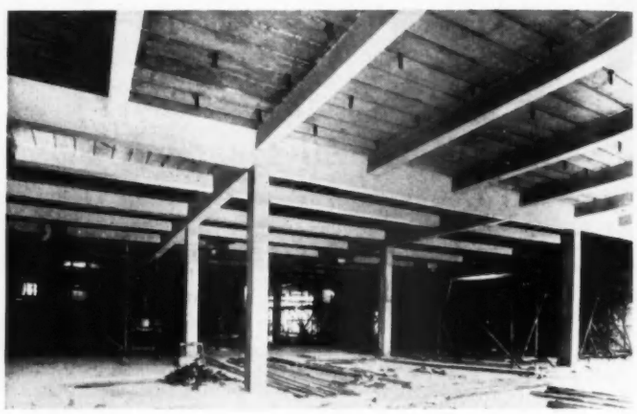


The cargo transporter LEFT was built for the S.S. "Canberra" by the Carron Company and consists of a retractable boom which can be extended 30ft beyond the ship's side. Set inside the line of the side girders of the boom and bolted to the underside of the structure, are two "H" sections which serve as tracks for the supporting rollers of hoist-operated platforms. On these platforms motor cars or other cargo can be handled between the ship and the quayside.

Structures The Garret Hostel footbridge, over the River Cam, exemplifies the lightness and beauty typical of modern concepts in structural engineering. The bridge spans 80ft, and is a two-pinned portal in prestressed concrete. After all the cables had been stressed, two 100-ton jacks were used to spring the portal to its designed thrust, this operation also being the first stage in striking the shutters. Engineer and contractor, J. L. Kier and Co., Ltd., in co-operation with the Cambridge City Surveyor.

A development in the use of structural steel for multi-storey buildings which occurred in 1960 was the introduction of lightweight vermiculite plaster as an encasement, in place of the cumbersome concrete encasement stipulated hitherto for fire-protection of the steel. Several methods of using the lightweight plaster were introduced, depending either on the use of light wire mesh reinforcement and mechanical methods of placing the plaster, or of making box-like shapes from panels of the material. The new British Home Stores building at Crewe shown ABOVE RIGHT has 1in thick vermiculite plaster panels fixed by Pyrotherm (Tomkinson Investments) Ltd. round the steel from stirrups on the top flanges. This encasement gives a two-hour fire rating to B.S.476, and is conveniently erected from portable staging.

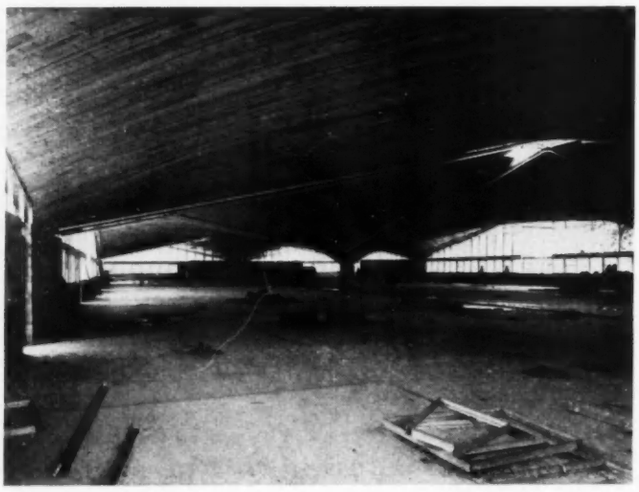




The merits of hyperbolic-paraboloid shells as an economic form of roofing factories and storage buildings are becoming increasingly recognised. We illustrate two examples of this trend constructed in 1960. BELOW RIGHT are reinforced concrete shells of this kind at the factory of Texas Instruments, Ltd., at Bedford. A group of four shells covers a square of 48ft. There are edge-beams round the periphery of each shell, and the four beams at the junctures of the constituent shells in each "umbrella" carry the compressive loads to the central column. The concrete in the shells is 2½in thick, and is in pure shear at a design stress of 82 lb per square inch. Consultants, Oscar Faber and Partners; contractor, Tarmac Civil Engineering, Ltd.

BELOW LEFT, eight hyperbolic paraboloid shells, each 60ft by 60ft, at Market Drayton which are built in timber. The straight-line generators of this type of shell make timber a particularly favourable material, and these shells consist of four layers of tongued and grooved boards, nailed and glued. The edge beams are glued, and there is glazing between the shells. The shells are carried by reinforced concrete buttresses, which obviate the need for the ties used in earlier examples of this type of construction. Consultants, Hume and Tottenham; shell contractor, Wheelers (Sudbury), Ltd.

The Swedish HB system of timber construction was used in this country last year to build a hangar at Gatwick Airport, and the storage shed at Deptford ABOVE LEFT. The system relies on nailed boards, the nails being detailed precisely for length and spacing in design. The shed spans 120ft and is 100ft long plus a 35ft cantilever. Designers and builders, Beves (Structures), Ltd., in collaboration with T. F. Burns and Partners.

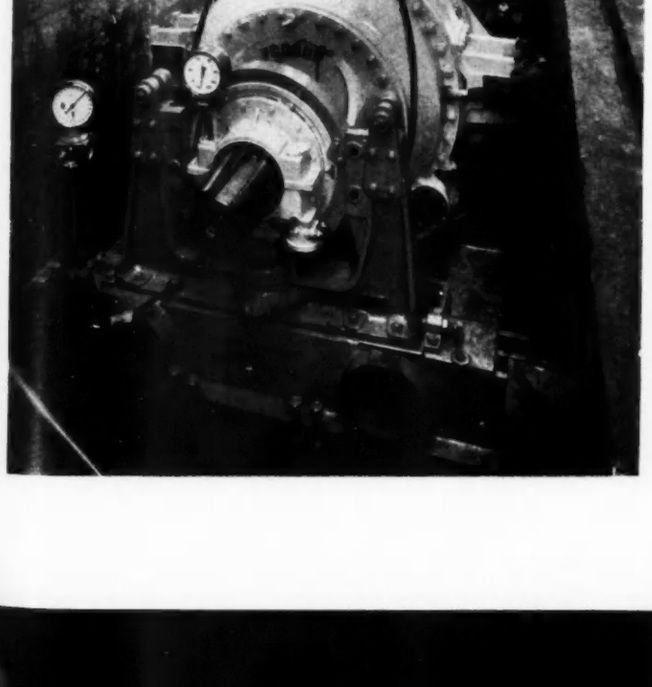


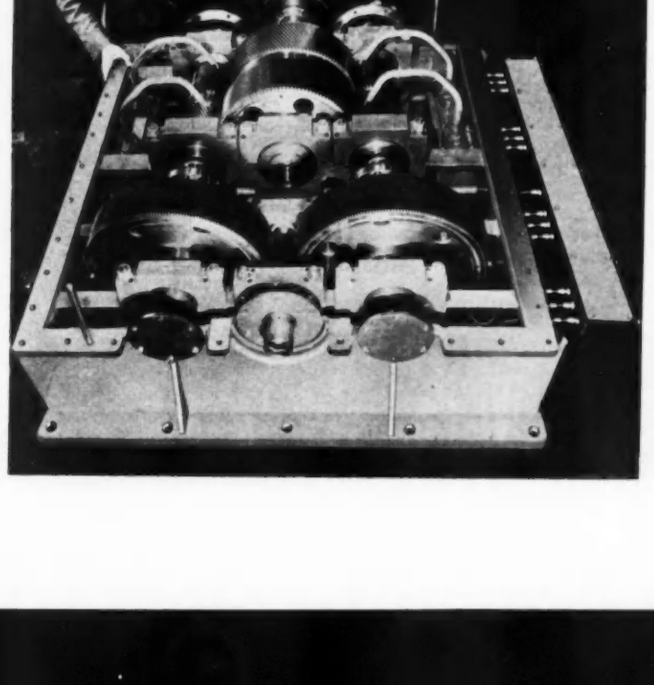
Exports of British Engineering Equipment

IT would be difficult indeed to give a true impression of the diversity of engineering products which this country exports, but these three illustrations indicate the nature of some of the equipment delivered to overseas customers in 1960. The mobile rock drilling rig, shown undergoing tests on the RIGHT, is one of fifteen such machines designed and built by the Climax Rock Drill and Engineering Company, Ltd., in conjunction with F. Taylor and Sons (Manchester), Ltd., for Russia. The telescopic towers of these machines enable holes to be drilled in the face up to 32ft above ground level. Each tower platform carries four hydraulic booms each with a Holman rock drill mounted on a power feed cradle, giving a feed length of 13ft and covering a horizontal working span of 24ft.

The dynamometer illustrated BELOW LEFT was manufactured by Heenan and Froude, Ltd., for installation in the works of Burmeister and Wain, of Copenhagen, and it is claimed to be the largest and most powerful dynamometer ever exported from this country. This dynamometer, which weighs over 80 tons and is intended for use in testing large diesel engines, is capable of absorbing and measuring up to 30,000 b.h.p. at speeds between 100 and 225 r.p.m. Engines of either direction of rotation can be tested by coupling up to the appropriate end of the dynamometer shaft.

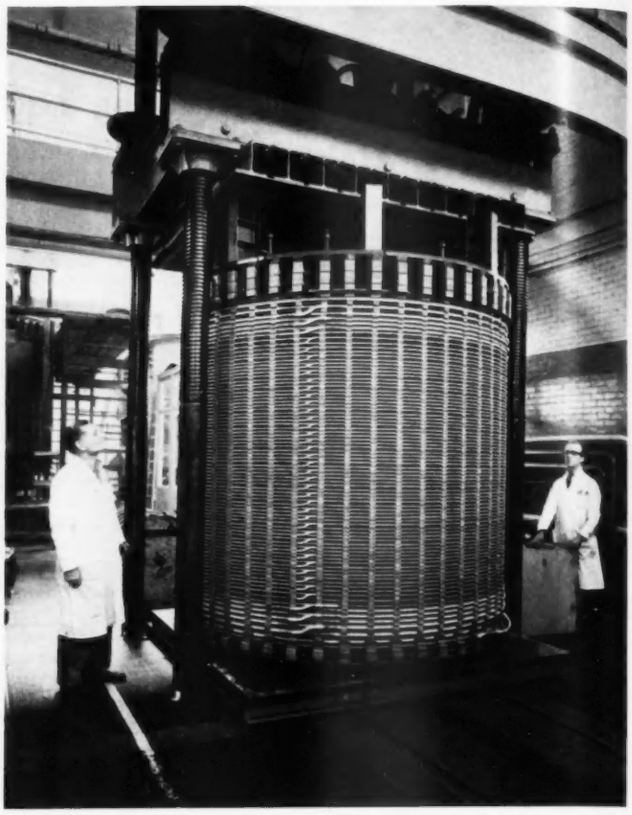
Particular interest attaches to a speed increasing gearbox BELOW RIGHT which was designed and manufactured in only five months by the heavy plant division of Associated Electrical Industries, Ltd. Built for gas turbine development work at the factory of the Canadian Pratt and Whitney Aircraft Company, Ltd., it is designed to transmit 2000 h.p. with a speed increasing ratio of 1700/44,840 r.p.m., provision being made for future modification to give an output speed of 55,000 r.p.m. The output gears of this equipment are believed to run at a higher pitch line speed than any gearbox hitherto made in this country.

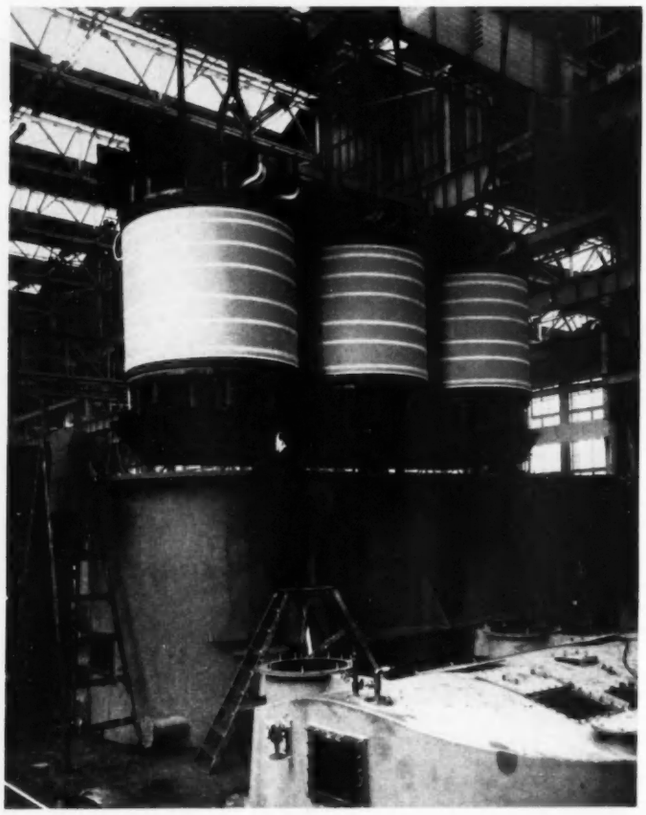




Power Transformers

TWO rectifier transformers are being built by Fuller Electric, Ltd., Walthamstow, for installation at the Lydd substation of the cross-Channel d.c. power cable link between the British and French electricity supply networks. Each transformer has three windings, with a no-load voltage ratio of 284/83 · 6/33kV, and a tapping range of ±15 per cent, controlled by a Fuller high-speed resistor-transition on-load tap changer. The innermost winding is a multi-start coil embodying the regulating tappings associated with the 275kV winding. Next, outwards from the core is the main 275kV, 95MVA, star-connected winding ; its unusual location near the core is dictated by impedance requirements associated with the a.c./d.c. converter plant. Next is the 33kV, 65MVA, delta-connected winding for supplying the capacitor bank which provides reactive power for the commutation of the valve converters ; this winding also provides the main auxiliary supply for the station Finally the outer winding (95MVA at 83 · 6kV) feeds the anodes of the valves and has 132kV-class insulation. This winding has an outside diameter of 7ft 8in. The windings are subjected to preshrinkage treatment in a 200 ton press and the illustration ABOVE shows the 83 · 6kV winding being so treated.

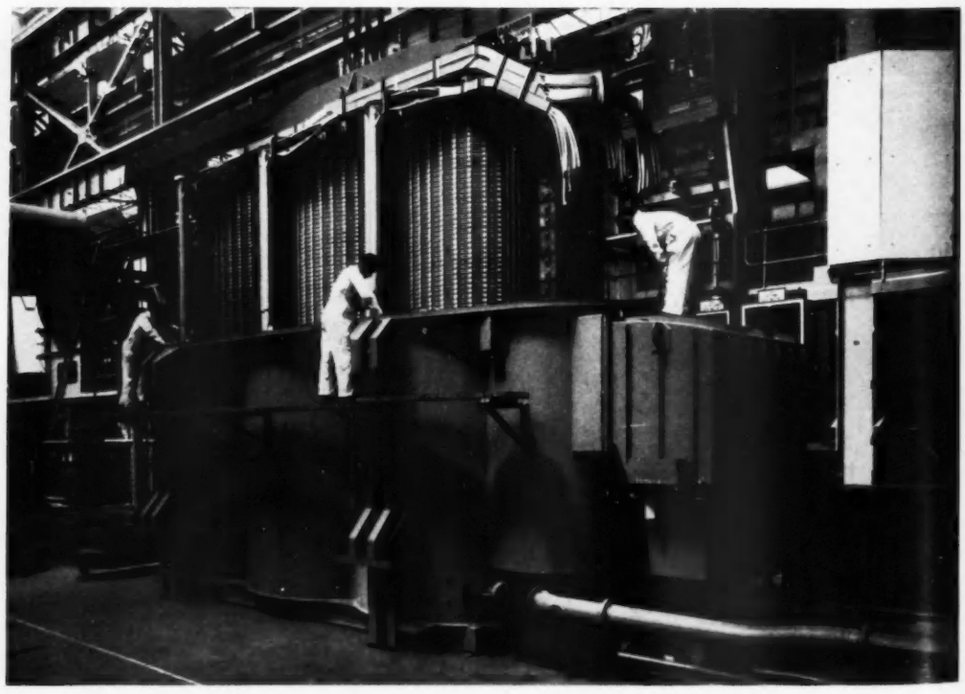




To control the leakage flux (of the order of 29 per cent) and avoid overheating of magnetic parts, such as core clamps and tank, a special method of shielding is used. It consists of cladding the main core supports with copper and enclosing the complete wound transformer in an aluminium lining inside the tank, which is shaped to follow closely the contour of the windings. The three-limbed core of cold-reduced grain-oriented sheet contains 89 tons of active material. Each transformer, stripped for transport, weighs 154 tons and, ready for service, 290 tons. Because of restrictions in the transport height the clearance between the top yoke of the transformer and the underside of the cover is limited to 1½in.

The second illustration, ABOVE, shows the completed core and winding assembly of a Ferranti 225MVA, three-phase, 16/295kV generator transformer (for Willington "B" power station) being lowered into its tank at the maker's works in Hollinwood, Lancs. This transformer is equipped with resistor type on-load tap changing gear and is oil-forced-water cooled. Cooling oil entering at the bottom of the tank is directed by special ducting in the winding supports to the axial ducts in predetermined proportions. The transport weight of the transformer is 180 tons. Before despatch the transformer was subjected to full-load temperature rise tests and impulse tests at 1050kV (full wave) and 1210kV (chopped wave).

The third illustration, RIGHT, shows the core and windings of a 210MVA, 16 · 2/295kV transformer being lowered into the tank at the new transformer factory of The English Electric Company, Ltd., at Stafford. This factory was described in "The Engineer" October 21, 1960.



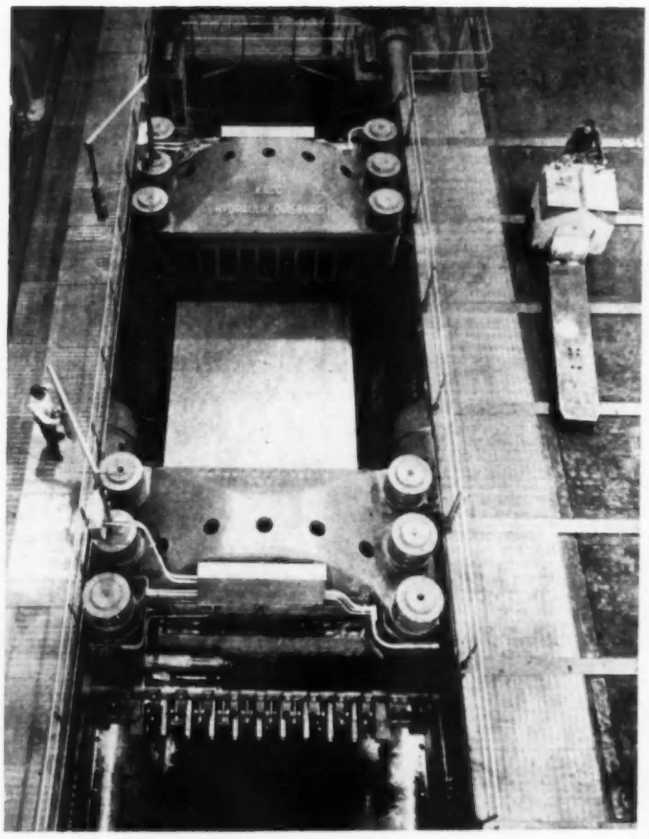
Heavy Manufacturing Plant

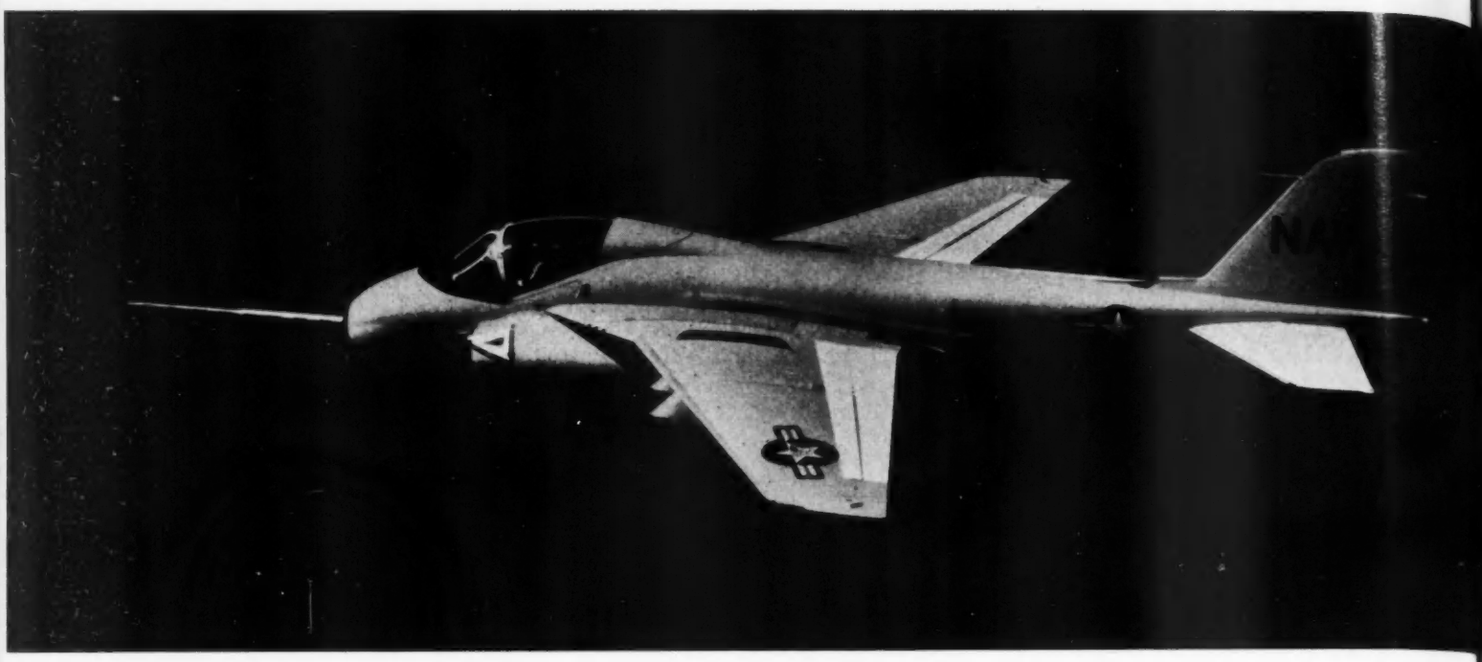
SOME recent heavy equipment furnished by Continental makers is illustrated on this page. Capable of a clamping force of 2500 tons, the Triulzi, Milan, injection moulding machine, RIGHT, develops an injection pressure of up to 22,000 lb per square inch, the ram force amounting to up to 220 tons. The high-speed plunger of the machine can inject shots of plastics material of up to 425 oz; the cycle is fully automatic.

Our second illustration, BOTTOM LEFT, shows a heavy lathe made by Maschinenfabrik Deutschland A.G., Dortmund. The lathe has a centre height of 1600mm, and a largest distance between centres of 33,000mm. The maximum weight which may be carried between centres without additional supports is 180 tonnes. A 270 h.p. motor is used to drive the headstock spindle, and develops a torque at the faceplate of up to 50,000 mkg. There are three saddles of which two are in front and one is at the rear. One of the front saddles is equipped for screw-cutting over the whole length of its tool-post slide. Also available is a boring device capable of boring holes of 580mm to 1000mm diameter to a depth of up to 23,500mm. Headstock and saddles are remotely controlled.

Claimed to be the largest in existence, the plate stretcher, BOTTOM RIGHT, recently came into service at the Ravenswood, Virginia, aluminium rolling mill of Kaiser Aluminium and Chemical Corporation. It is used for improving the quality of aluminium alloy plates and sheet required by the aeronautical, shipbuilding and automobile industries as well as the chemical industry. The stretcher was delivered by Hydraulik G.m.b.H., a subsidiary of Demag Aktiengesellschaft, Duisburg. It is mounted in a pit 120ft long, 32ft wide, and 15ft deep. Principally, it consists of two clamping heads with hydraulically operated jaws, two hydraulic cylinders for separating the jaw heads, and two columns for transmitting between the clamping heads the reactions of the stretching cylinders which operate at up to 6000 lb per square inch and together can develop a stretching force of 13,600 tons. Made of forged steel, the columns have a diameter of 3ft 6in and are 35ft long. Each clamping head weighs 265 tons.

The jaws can accept plate up to 13ft wide and 6in thick, and plates up to 60ft long can be stretched by up to 8 per cent. Should one of the plates tear under load the energy released is absorbed by buffer cylinders and other safety devices.





Low Flyers Operation at low altitudes has significant advantages for military missions, particularly that the air crew can see better and be seen less well. The Grumman Aircraft Engineering Corporation has developed specialised low-flying aircraft for both the Navy and the Army of the United States, the one for attack and the other for observation duties.

The "Intruder" ABOVE is a carrier-borne machine of transonic or high-subsonic cruising speed, and is distinguished by its use of jet deflection; while the ability of this technique to reduce flying speeds even to zero was demonstrated more than three years ago by the Bell X-14, this is the first instance of it being exploited in a production aircraft. The angle of deflection is not large, even as on the experimental "Meteor," and in contrast with that machine a single movable nozzle is fitted to each engine; the deflection referred to the gravity field is, however, large in the low speed regime because of the wing sweep and the extensive leading-edge slots. Since carrier landings are always into a wind of significant strength, it is needless to reduce the flying speed so low that conventional controls are not effective. Presumably to reduce the stowage length of the "Intruder," the crew of two sit side by side, which will probably be advantageous in teaching what may be a quite different technique in piloting, since the direction as well as the magnitude of the thrust is now controllable. The engines mounted close together under the centre section are Pratt and Whitney J-52 compound turbo-jets with, of course, no afterburners.

The "Mohawk" is designed for battlefield reconnaissance and is seen BELOW equipped with the elongated antenna of the SLAR (Side-Looking Airborne Radar); also conspicuous is the copiously glazed cabin, again with side-by-side seating. This aircraft employs no specialised S.T.O.L. techniques, but has a good field performance by virtue of its high power; the big round cowlings each house a reverse-flow Lycoming T-53 of 1000 h.p. These engines, while not of extreme power-weight ratio, are mechanically simple and designed to need only the minimum of support facilities.

Dams Grande Dixence dam BELOW in the Valais, Switzerland, reached its full height of 932ft by October, 1960 and will be completed this summer. The whole scheme will yield about 10 per cent of Switzerland's present energy production. The reservoir will have a capacity of about 325,000 acre-feet, sufficient for 85 per cent of the scheme's energy to be generated in the winter.

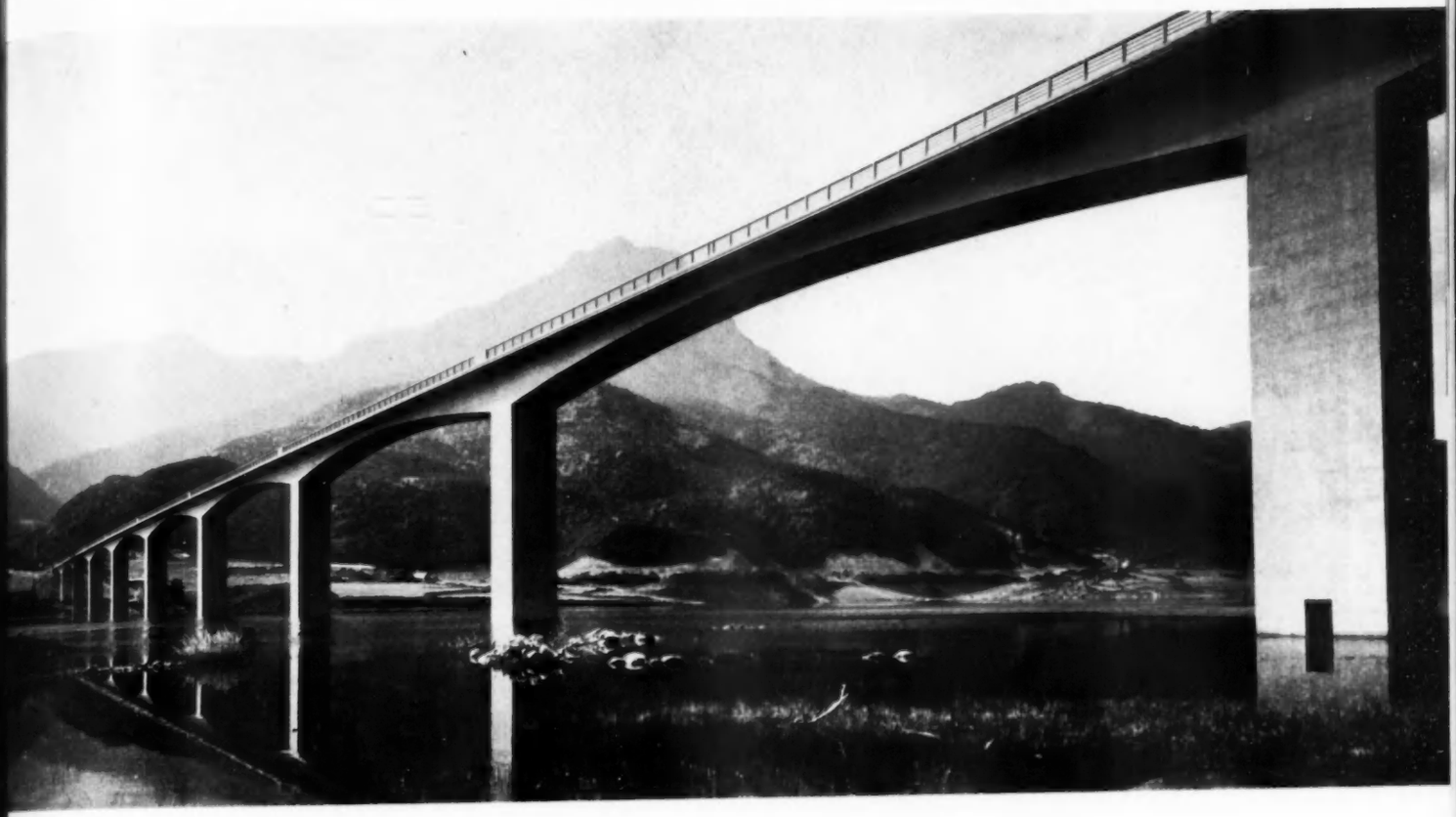
ABOVE Kariba Dam, July, 1960. The water level had risen 230ft since impounding started in December, 1958, and about 51,000,000 acre-feet of water had been stored, inflows varying between about 200,000 cusecs and 9500 cusecs. At the rate of filling so far, normal top water level will be reached by the end of 1963. Three generators were commissioned in 1960.

Roselend and Serre Ponçon

TWO important French power dams which progressed substantially towards completion in 1960 are illustrated. Roselend dam BELOW in Savoie forms an important seasonal storage reservoir on the right bank of the Isère River, to which right bank tributaries will be diverted from the watershed of the catchment already diverted into Tignes reservoir, as far as the Doron de Beaufort, a tributary which flows into the Isère close to Albertville. The structural concept of the dam is unique. The deep gorge is closed by an arch dam about 140m in height; the abutments of the arch extend up to the rock surface at about the 1500m level, and the crown of the arch is at 1560m, the "crest" thus forming a sloping curve, approximating to the line of thrust in the arch, the start of which can just be seen on the left-hand side of the deep gorge in the illustration. The shallower part of the valley is closed by a buttress dam, which closes off the triangular spaces left on each side of the crown of the arch dam. Several of the buttresses are carried directly by the arch.

A pressure tunnel and a single buried penstock serve the power station—La Bathie—associated with the reservoir, where five 100MW Pelton wheel generating sets are installed. Annual output about 10^9kWh; gross head 1200m; rated flow 50 cumecs; storage capacity 200×10^6 cubic metres. The power station is the largest hydro-electric station in France and is important for peak loads and frequency regulation.

Serre Ponçon dam OPPOSITE is a rock-fill dam 120m in height above streambed, which forms a huge reservoir on the upper part of the Durance River, near the town of Gap (Hautes Alpes). The dam is shown from downstream, the tailrace of the underground power station associated with it and the spillway tunnel being visible on the right-hand side of the illustration. The reservoir has a capacity of $1{\cdot}2 \times 10^9$ cubic metres, and is the key to multiple-purpose utilisation of the river, irrigation lower down the valley and flood control being important objectives of the scheme. The dam has a cut-off formed by the Soletanche system of grouting which seals alluvial deposits which extend to a depth of 100m below the stream bed. Very extensive works were needed to re-establish communications in the reservoir area, the largest of these works being Savines bridge, shown in the upper view OPPOSITE, with the reservoir partially filled. The bridge is of prestressed concrete, constructed *in situ* by cantilevering successive steps of 3·55m symmetrically from each tower and then prestressing, using gantries carried by the bridge itself. The bridge has eleven spans each of 77m, and one span of 38·5m at each end.



Britain's Nuclear Power Stations

SIX nuclear power stations are now under construction for commercial service in Great Britain. Five of them are being built for the Central Electricity Generating Board: Berkeley, Gloucestershire (275 MW) by A.E.I.-John Thompson; Bradwell, Essex (300MW) by N.P.P.C.; Hinkley Point, Somerset (500MW) by English Electric-Babcock & Wilcox-Taylor Woodrow ; Trawsfynnydd, Merionethshire (500MW) by Atomic Power Constructions ; Dungeness, Kent (550MW) by The Nuclear Power Group. The sixth, Hunterston, Ayrshire (300MW) is being built for the South of Scotland Electricity Board by G.E.C.-Simon-Carves. Contracts have also been placed with English Electric-Babcock & Wilcox-Taylor Woodrow, for another C.E.G.B. station (580MW) at Sizewell, Suffolk. All these stations will have gas-cooled, graphite moderated reactors using natural uranium fuel in " Magnox " cans. The C.E.G.B. has also received consent for a nuclear power station to be built at Oldbury-on-Severn.

Here we illustrate the first four of these stations, considered chronologically. On the page opposite we show, CENTRE, the reactor buildings at Bradwell ; and, TOP LEFT, a view of the charge face of No. 1 reactor at Bradwell, showing the standpipes and equipment through which the control and fuel handling equipment will operate with the reactor on load. There are eighty-eight refuelling standpipes to serve thirty-four fuel channels and 168 standpipes for control rods, fission product detection devices, &c.

The other two pictures OPPOSITE show, BOTTOM, the reactor buildings at Berkeley, and TOP RIGHT, the pile cap of No. 1 reactor, with the charge face nearing completion in readiness for the installation of the charge and discharge machinery. Berkeley and Bradwell are due to be on commercial load by the end of this year.

ABOVE we reproduce an aerial view of Hinkley Point under construction, showing the switch yard, the two reactor shells the " Goliath " crane and the turbine hall. Work on site began in December 1957.

BELOW is an aerial view of Hunterston where, after earlier delays due to labour troubles, site work is now proceeding to a schedule which envisages the first reactor being on load for the winter 1962/63.

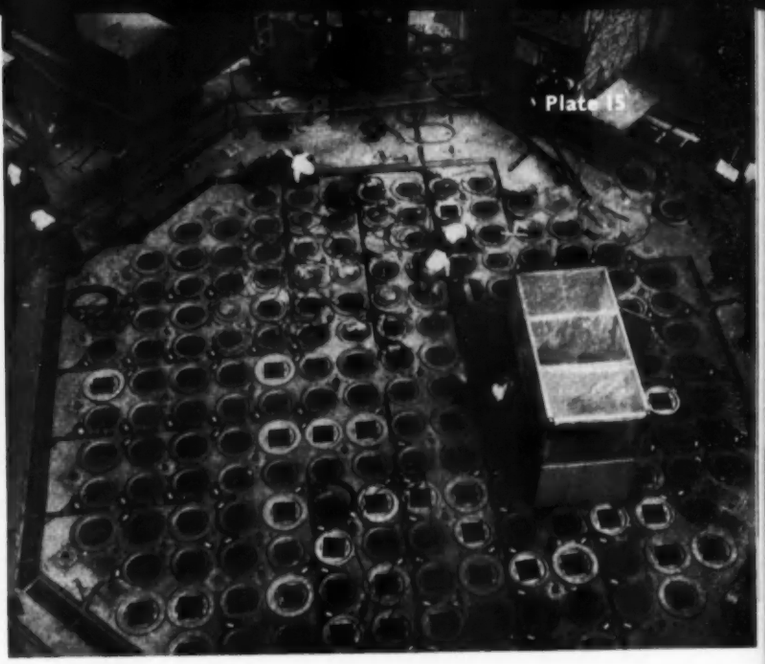
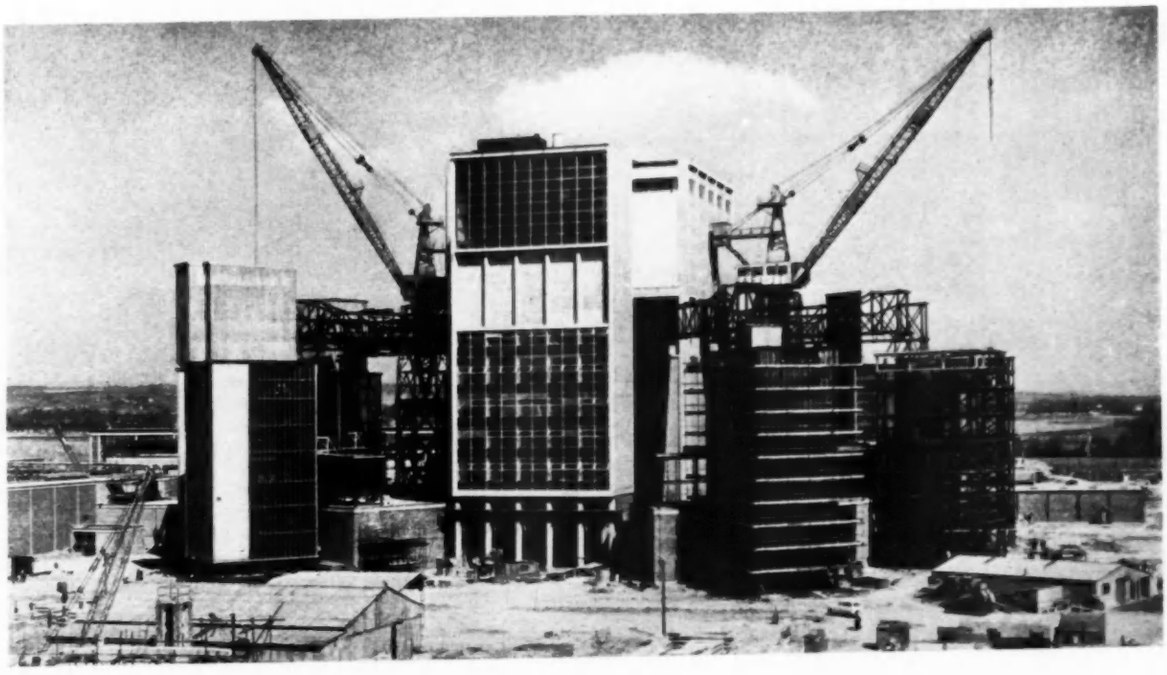
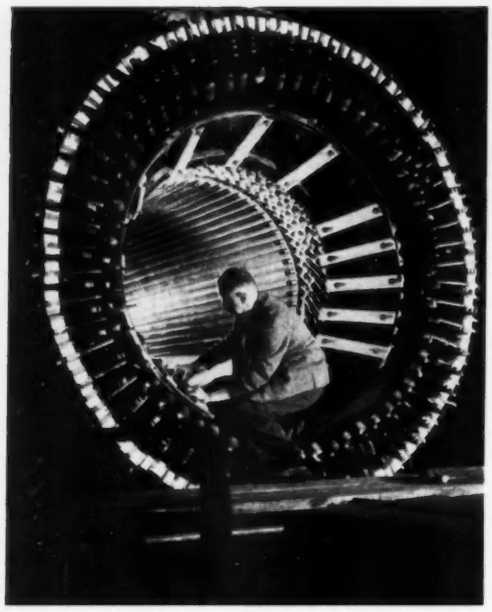
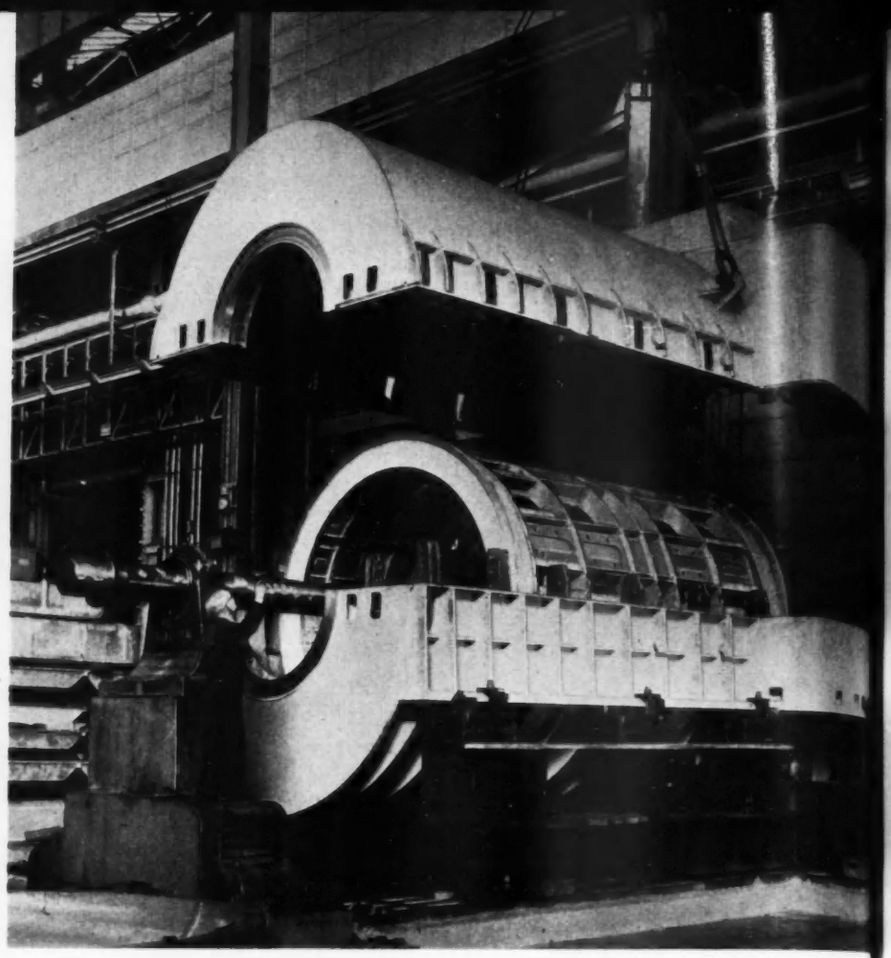


Plate 15



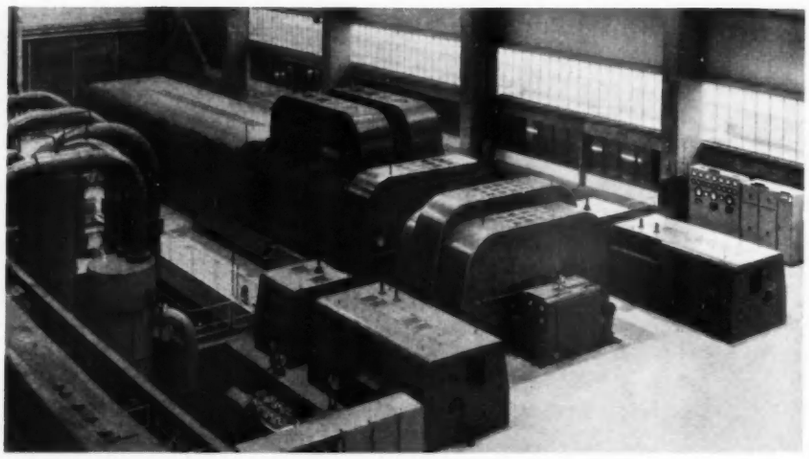
Steam Turbo-Generators

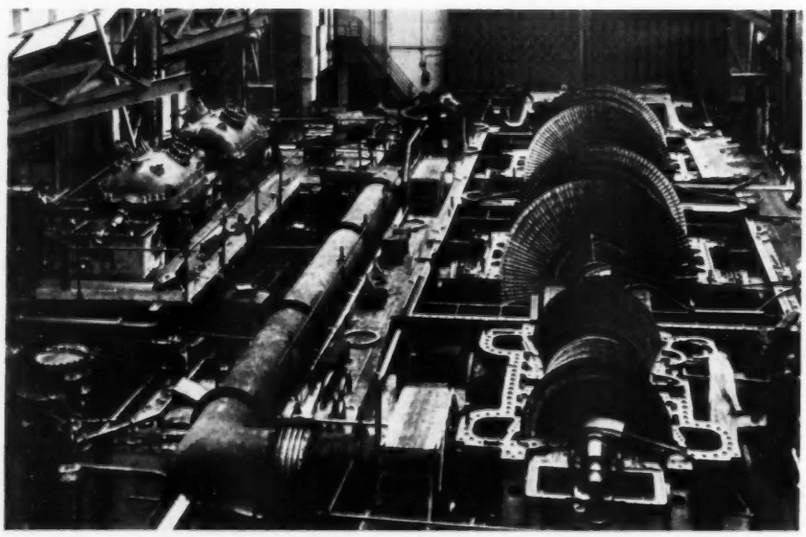




CONTINUED progress in the design and development of coal-fired power generating plant was described in the annual report of the Central Electricity Generating Board for the year ended March 31, 1960. As a result of this progress orders have been placed for 300MW, 350MW and 550MW generating units. The latter involves a two-shaft generating set and all the units referred to above are designed for steam conditions of 2300 lb per square inch and 1050 deg. Fah. with reheat to 1050 deg. Fah. Orders have also been placed for two 375MW generating units to work at a super-critical steam pressure of 3500 lb per square inch and a temperature of 1000 deg. Fah. with 1050 deg. Fah. reheat. Studies have shown that a single-line turbo-generator of 500MW capacity is practicable.

Developments such as these are "on the drawing board." Typical examples of present-day British practice are illustrated on this page. The picture ABOVE shows the winding of the water-cooled stator of a 200MW turbo-generator at the Trafford Park works of A.E.I., Ltd. The set is for installation in the C.E.G.B's Willington "B" power station.

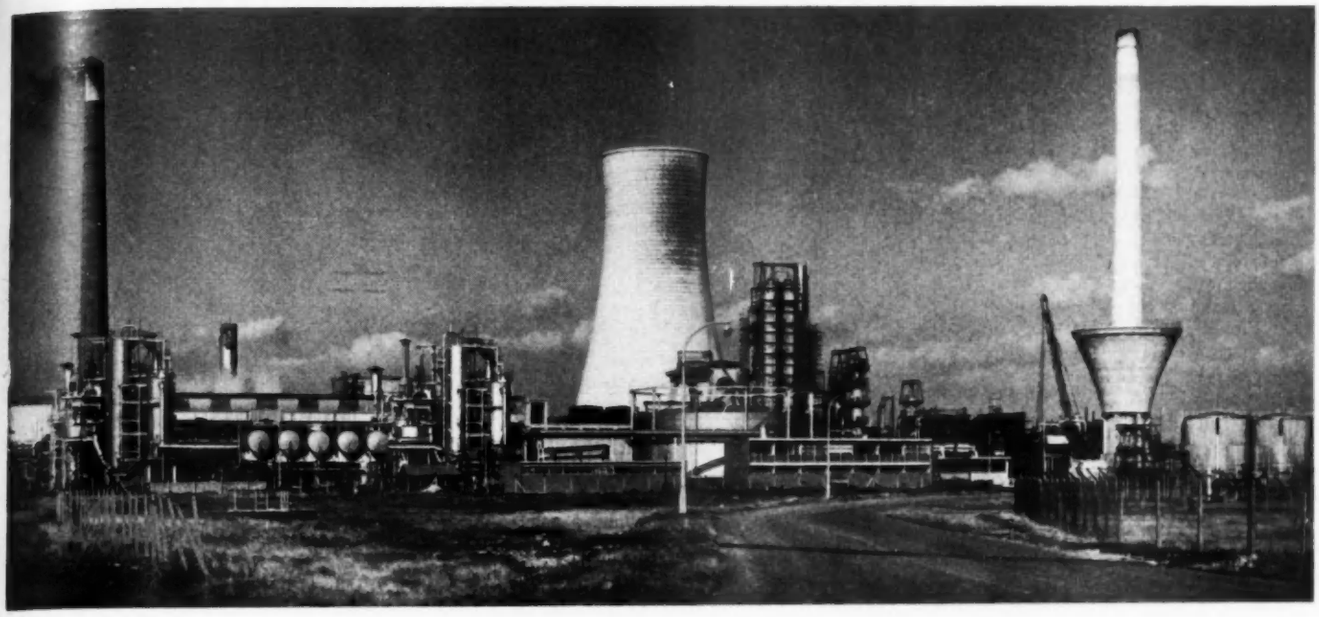




The picture, TOP RIGHT, shows the top half of a 200MW alternator stator shell being lifted after the bore of the inner stator casing had been machined at the Witton (Birmingham) works of the General Electric Company, Ltd. This company is supplying two such sets for the South of Scotland Electricity Board's Kincardine "B" power station. To reduce the transmission of vibrations from the inner stator casing to the foundations, the casing of each machine is fixed to the outer shell by four axially located leaf springs.

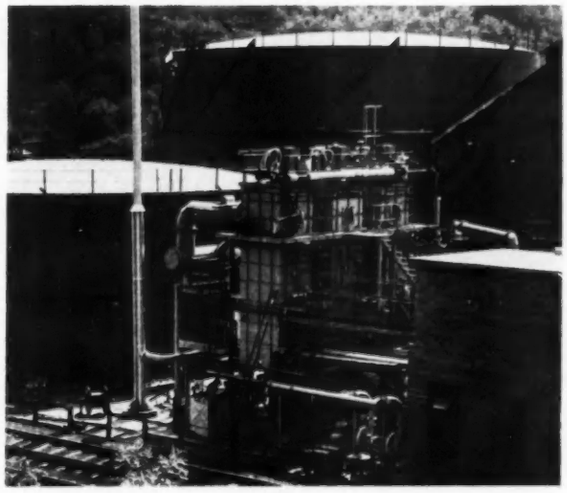
The first 200MW steam turbo-generator to come into service in Europe was an English Electric set which was commissioned by the Central Electricity Generating Board at High Marnham power station, Notts., in October 1959. When this station is completed it will contain five similar sets; two are now in service and one is illustrated ABOVE.

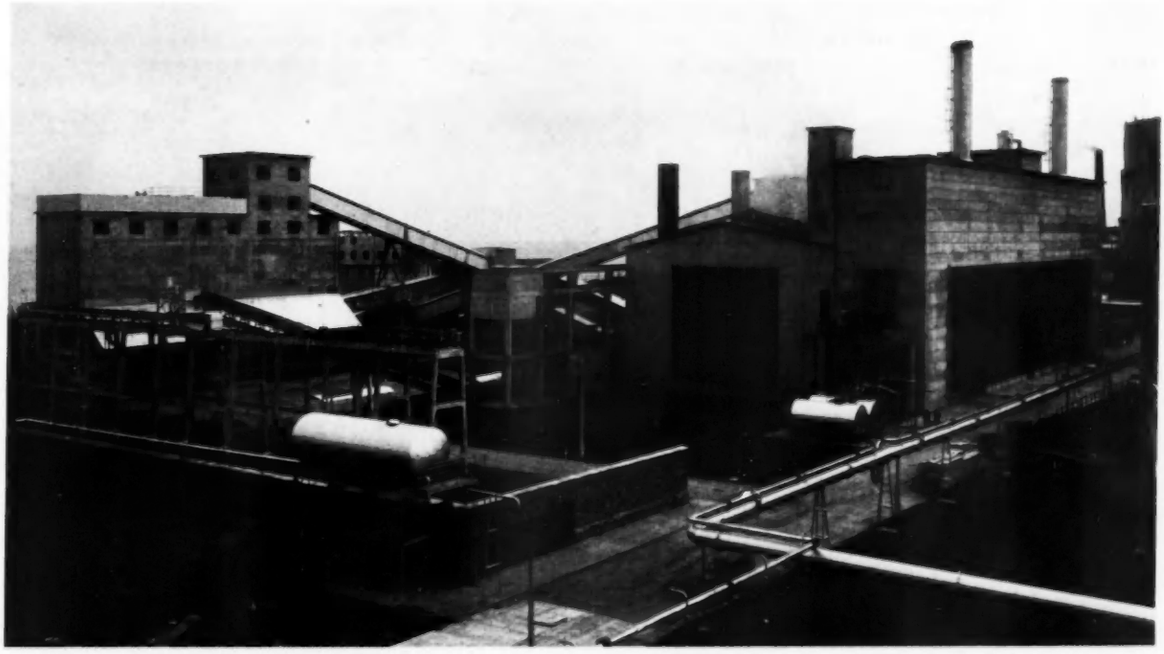
The fourth illustration on this page, LEFT, shows a 300MW cross-compound turbo-generator, for Lakeview power station Canada, being erected at the Heaton Works of C. A. Parsons and Company, Ltd. This, the first of two similar machines for Lakeview, has been completed and despatched to site. Another export order completed by the same manufacturer concerns the Richard L. Hearn power station, Toronto where the fourth 200MW Parsons set is now in service.



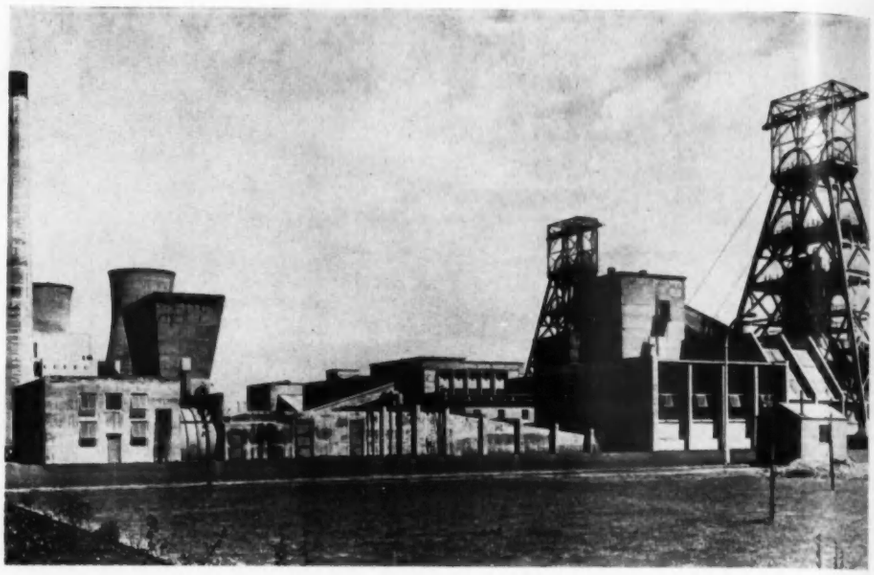
Gas The diverse nature of some of the 1960 projects of the gas industry is shown by our three illustrations. Development continued at the Isle of Grain, Kent on the oil gasification plant ABOVE built by the South Eastern Gas Board to take a supply of raw material from the adjacent refinery of the British Petroleum Company. The first stage of this project, with a capacity of 20,000,000 cubic feet of gas a day, operates on the Segas process. The second stage will raise this capacity to about 45,000,000 cubic feet ; and a third stage will bring daily capacity up to 70,000,000 cubic feet. The process in the two second stages of development is slightly different in that the components of low calorific value are manufactured separately from the enriching components. For the production of the "lean" gas the "Shell" process is being employed. Enrichment can be obtained either from the existing plant or by refinery tail gas and subsequent blending.

The first natural gas supply in this country was introduced at Whitby this year. Some 4,500,000 cubic feet per day of methane gas is tapped from wellheads in Eskdale and delivered by a main at a pressure of 200 lb per square inch to Whitby gasworks where it is reformed by the plant shown on the RIGHT. Typical of modern conventional carbonising plants is the plant completed this year at the Sunderland works of the Northern Gas Board illustrated BELOW This plant produces some 8,000,000 cubic feet of gas a day.



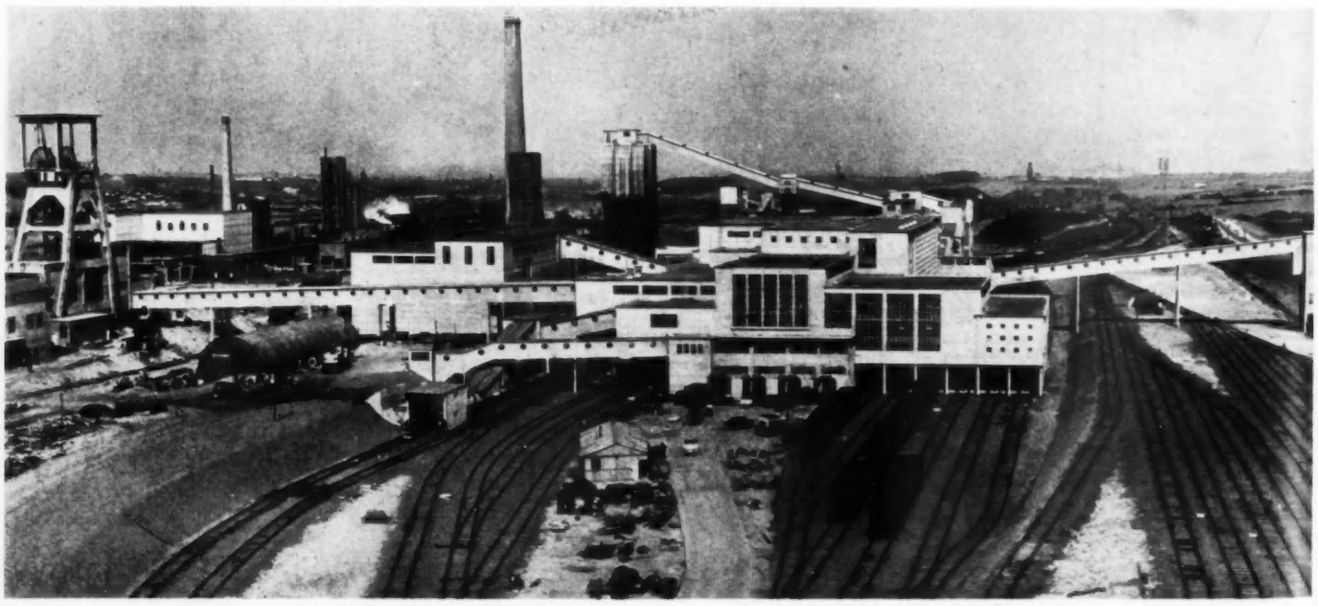


Coal During 1960 the new mine and modernisation projects being carried out under the National Coal Board programme and described in our columns included those at Lea Hall, Cynheidre and Hawthorn. The new Lea Hall colliery RIGHT, has given a new lease of life to the Cannock Chase area. For this mine two new 1300ft deep shafts have been sunk, and when it is fully extended some 23 miles of underground roadways will give access to eleven seams, with certain reserves of almost 148 million tons of coal. It is planned to produce up to 1,500,000 tons of coal a year and, using extensive mechanisation, obtain an output of 43 cwt. per manshift. When the workings are fully extended this new mine will have cost about £14,000,000.



The Cynheidre colliery, to be seen during its construction on the LEFT, has been one of the most complex projects undertaken by the N.C.B. Under this scheme to-date two new 800-yard-deep shafts have been sunk, 13 miles of tunnels driven, and five pit bottoms constructed. The colliery will eventually work anthracite reserves in eight seams by horizon methods and the production by 1963 is expected to be some 2200 tons a day.

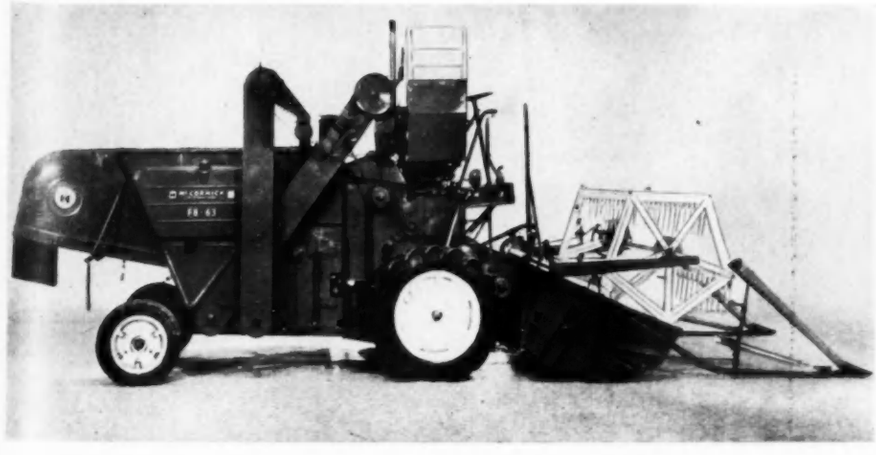
The main site of the Hawthorn combined mine in the Durham Division No. 2 area is illustrated BELOW. Under this scheme the Murton, Eppleton and Elemore collieries have been connected by an underground locomotive haulage system by which all the coal produced is delivered for raising at a new shaft. This scheme has extended by some sixty years the economic lives of the three old collieries which, with extensive modernisation and mechanisation, have a planned combined annual output of 1,600,000 tons of coal. New washing and carbonisation plants built adjoining the new shaft treat the combined output of the mines.



Agricultural Machinery

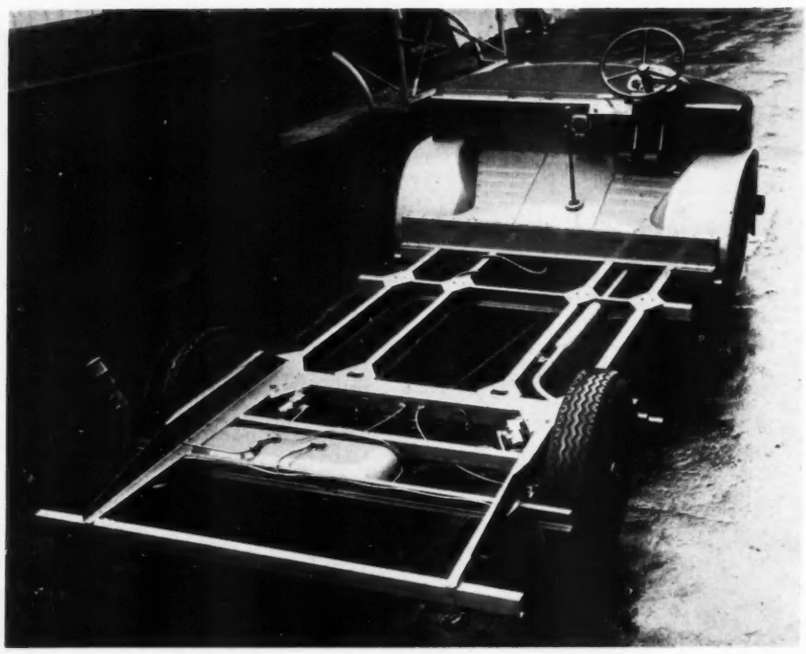
TRACTORS are constantly being improved. Disc brakes and a differential lock are nowadays almost standard equipment, whilst hydraulic draught control, exhaust brakes, four-wheel drive and power steering are available on several of the modern tractors. The hydraulic equipment of the Fordson " Super Major," illustrated ABOVE RIGHT, incorporates the " Qualitrol " system giving effective depth control by implement draught, which enables work to be continued in spite of changing soil conditions and ground contours normally resulting in loss of wheel grip. Position control, allowing an implement to be automatically maintained in its position relative to the tractor irrespective of changes in soil resistance, is obtained by the lift arms being set in pre-determined position by cam and follower on the cross shaft. The " Super Major " is fitted with a differential lock, self-energising double disc brakes, and three-point linkage accommodating both Category 1 and 2 implements. Petrol and diesel-engined versions of the tractor are available the latter giving 51·8 b.h.p. at 1600 r.p.m.

The Massey-Ferguson 65 Mk. II tractor, shown ABOVE, has a direct injection Perkins 203 cubic inches engine giving 56·5 b.h.p. at 2000 r.p.m.; a special cold-starting version is available. It has self-energising double disc brakes, a pedal operated differential lock, swinging drawbar, lights and dual category linkage ends fitted as standard equipment. Power steering can be fitted as an optional extra. The four-wheeled general-purpose agricultural tractor of Allis-Chalmers Great Britain, Ltd., model ED-40, shown ABOVE, is powered by a Standard-Triumph four-cylinder diesel engine giving 37 b.h.p. at 2000 r.p.m. The transmission provides eight forward and two reverse speeds—from 0·92 m.p.h. to 15 m.p.h. A built in selective weight transfer system, which is an integral part of the hydraulics, enables weight from the implement to be transferred to the tractor rear wheels without affecting the working depth of the implement. An adjustable depth stop maintains the implement at the correct working depth regardless of land conditions. Differential lock will be offered as optional equipment in the near future. The F8-63 self-propelled combine harvester, LEFT, is manufactured by Compagnie Internationale des Machines Agricoles, the French affiliate of the International Harvester Company of Great Britain, Ltd. It is powered by an indirect injection four-cylinder diesel engine developing 35 b.h.p. at 1875 r.p.m. The effective cutting width of the F8-63 is 7ft. It has a combination tanker and bagger attachment.



Automobile Engineering

DISPOSING the passengers in a car becomes an increasingly acute problem as the required performance increases. The conventional solution tends to result in a nose-heavy vehicle which is unresponsive at high speeds and has limited space in and poor access to the rear seats. The rear-engined vehicle enjoys excellent traction but the wheelbase becomes a compromise between leg room for the front seats and weight distribution (tyre and wheels sizes, of course, usually remain the same for all wheels). A radical approach to these intractable problems is the Ghia "Selene," RIGHT, in which the driving seats are set ahead of the front wheels. The main cabin has four seats in facing pairs. The power unit would be accommodated in the tail, so that even when only a driver is in the car the traction should be adequate and the weight distribution favourable. The illustration shows a mock-up with dual control, there being two pedals and a set of instruments before each front seat.



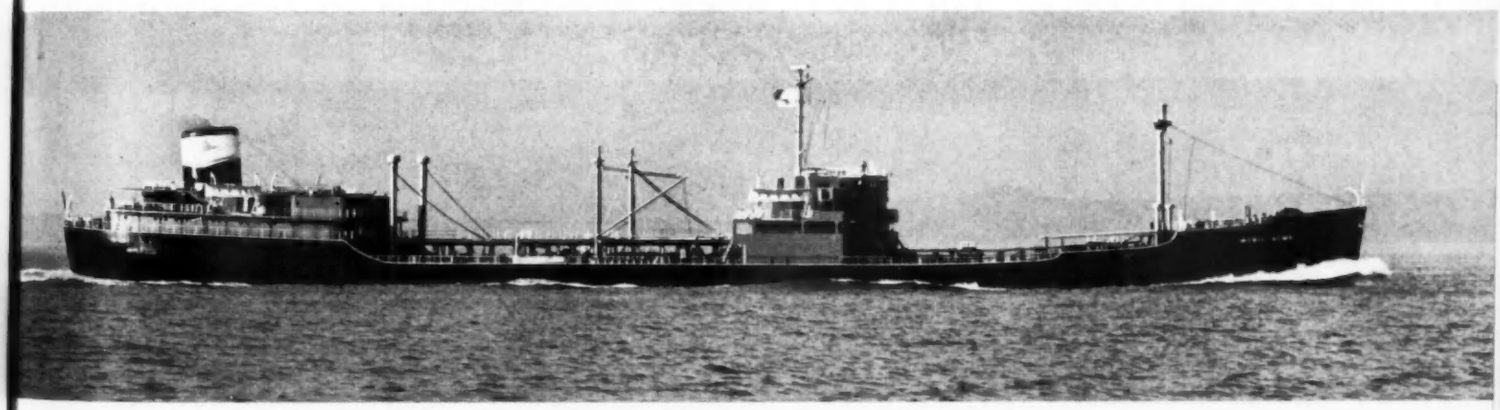
In the commercial vehicle also such necessary burdens as the engine often intrude upon the crew or the freight accommodation, and the problem of the variation in the ratio of sprung to unsprung weight from laden to empty is acute. A fundamental solution is to carry the engine on the driven wheels, and to avoid an intolerable ride for the crew when unladen this implies front wheel drive. An example of this approach is afforded by the Dennis "Vendor" LEFT which is designed as a mobile shop with easy access from the cab to the body proper. Our illustration shows the conspicuously low level of the uninterrupted floor made possible by independent rear suspension; each rear wheel is located by a single trailing arm, a rubber compression spring, and a lever damper. Since a shop will probably be operated by a driver not selected for his skill, the vehicle is fitted with a three-speed synchromesh gearbox. In front of the scuttle is a Standard 2262 c.c. diesel engine, but the transmission has been designed to use up to 100 h.p. in other applications.

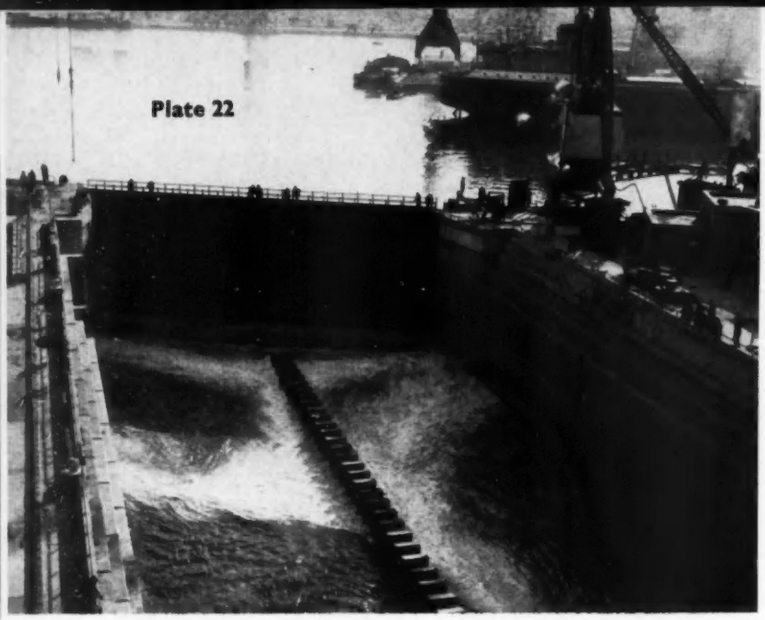
Last year Mr. Donald Campbell made an attempt on the world's land speed record with his "Bluebird" CN-7 (Campbell Norris 7) on the Salt Flats at Utah. The car is seen BELOW in between runs; it is standing on its built-in jacks, which are extended by the hydraulic power pack in the foreground, and on the body are seen the axial flow blowers cooling the heat sinks of the friction brakes—one of the air brakes can be seen immediately beside the port exhausts of the midships-mounted "Proteus". At the far end of the car the cockpit cover is erect, and on the transparent bubble canopy is hanging a fabric cover. The nearest crewman seems to have had some insight into the destiny of the 1960 attempt; on its sixth run the car was seriously damaged and the driver injured. At that time, late in the season for record attempts, the surface of the prepared strip, which is only 80ft wide, was deteriorating, and when accelerating fiercely up to an intended 300 m.p.h. the driver found adhesion inadequate to meet his control demands—a gusty wind was blowing at about 6 m.p.h. at an angle to the track—and the car diverged from the course. When facing almost at right angles to the direction of motion, the car turned over, although the centre of gravity is at a height less than half the track—this can be explained by the very large precessional couple developed by the great 52in wheels, which adds 10 per cent to the weight transfer in a steady turn and would be enhanced if the unstable aerodynamic yawing moment became dominant. It is believed that as the car settled rapidly towards the inverted attitude aerodynamic forces lifted it into the air and precessional couples ruptured the steering links, much of the damage to the car being done by the wheels striking the structure.

Tankers The Pacific Steam Navigation Company took delivery of the "William Wheelwright" ABOVE from Harland and Wolff, Ltd. The ship was built and engined at Belfast, and has a length between perpendiculars of 715ft by 98ft beam by 52ft 6in depth, and carries a deadweight of 47,200 tons. There are thirty-six cargo oil compartments and one main cargo pump room and the accommodation is air conditioned throughout. Electric power for auxiliary machinery and for ship's services is provided by two 740kW Allen turbo-alternators and by one 100kW diesel-driven alternator for port use. Propulsion is by a set of double-reduction geared turbines which develop 16,000 service s.h.p. and take steam at 600 lb per square inch and 900 deg. Fah. from two Babcock and Wilcox "Selectable Superheat" water tube boilers burning oil fuel under forced draught.

Alexander Stephen and Sons, Ltd., completed the "Mobil Acme" BELOW to the order of Mobil Tankships, Ltd., and the ship carries a deadweight of 19,000 tons on 30ft 9in summer draught and 18,300 tons on normal service draught of 30ft. The dimensions are: 525ft length between perpendiculars by 74ft moulded breadth by 39ft moulded depth. Cargo oil is carried in twenty-seven tanks, which are fitted with the Butterworth cleaning system, and handled by four 2000 gallons per minute horizontal turbine-driven pumps, together with two 400 gallons per minute vertical "Duplex" steam-driven pumps. A service speed of 15½ knots is maintained by a two-cylinder cross-compounded turbine which develops 9250 normal s.h.p. and drives a five-bladed propeller at 108 r.p.m. through double-reduction articulated gearing. Two Foster Wheeler E.S.D. boilers burning oil fuel under forced draught supply steam at 600 lb per square inch gauge and 850 deg. Fah.

The 37,000 tons deadweight tanker "Ellenga" BOTTOM was constructed at the Wallsend shipyard of Swan, Hunter and Wigham Richardson, Ltd., for the British India Steam Navigation Company, Ltd. and has the following dimensions: length between perpendiculars 660ft, breadth moulded 90ft, depth moulded 48ft, and draught 36ft 4½in. Amidships accommodation and the smoke room aft are air-conditioned. Thirty-three tanks, the majority cathodically protected, carry the cargo oil which is handled by four 1350 tons per hour Drysdale, one-stage, centrifugal pumps and two 330 tons per hour vertical "Duplex" stripping pumps. The electric power for the auxiliary machinery and ship's service is supplied by two 750kW Allen turbo-alternators, while for emergency and lighting-up duties there is an Allen 200kW diesel-driven alternator. Propulsion is by machinery built by Wallsend Slipway and Engineering Company, Ltd., consisting of a set of double-reduction geared turbines of 16,000 s.h.p. at 105 propeller r.p.m. and capable of driving the ship at a loaded service speed of 16 knots. Two Babcock and Wilcox selectable superheat boilers provide steam at 600 lb per square inch gauge and 850 deg. Fah., and burn oil under Howdens forced draught.





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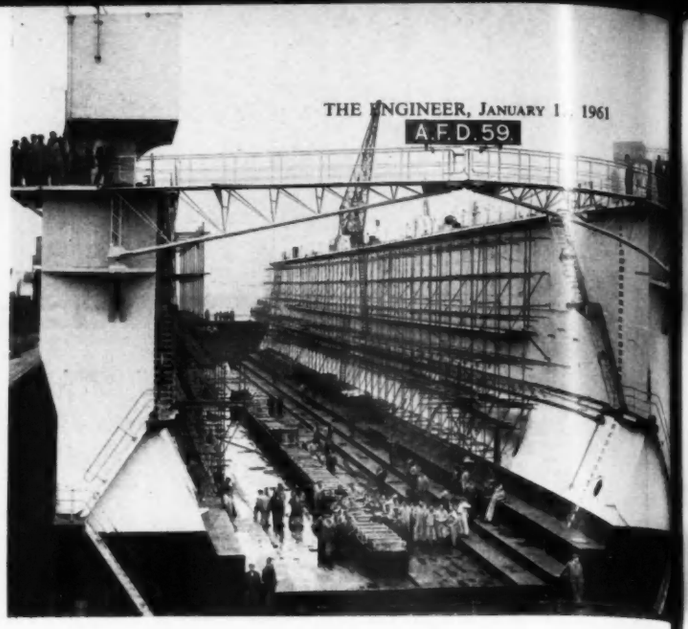


Docks and

THE Admiralty floating dock at Portsmouth ABOVE RIGHT is intended especially for servicing nuclear submarines and in addition to the normal services has living accommodation for about 200 persons. The dock is 400ft long, 77ft wide and 65ft high. It was extensively prefabricated and was completed in fifteen months.

Henderson dry dock ABOVE LEFT at Immingham Port was opened last October for the Humber Graving Dock and Engineering Company, Ltd. The dock entrance is in impounded water and is 90ft wide, (the same width as the Port entrance). The dock is 600ft long and has a depth over the keelblocks of from 22ft to 27ft, and will accommodate tankers up to 27,000 tons deadweight.

The ground consists of soft alluvial clay to a depth of about 45ft overlying a layer of very fine sand. The dock cross section has sufficient weight to resist the upward pressure of ground water in the fine sand layer on which the dock rests. Various other forms of construction were considered which would either reduce the water pressure in the sand or withstand it more economically, but they were not found to be appropriate to the ground conditions at this site. Excavation was in open cut to a depth of about 16ft then in steel sheet piled trenches for the walls, the dumpling between the walls being removed last. The dock entrance was constructed behind a temporary double-skin steel-sheet-piled cofferdam filled with chalk. Ground water had to be reduced by pumping from a system of deep wells all round the dock, the flow into which was increased with vacuum pumps.

The dock has a " Box " gate ; two 36in horizontal centrifugal main pumps are capable together of emptying it in about three hours. It can be filled in about three-quarters of an hour. Contractor, Mowlem (Civil Engineering), Ltd.; consulting engineers, R. T. James and Partners (civil) ; R. W. Gregory and Partners (electrical).

The new dry dock of Grayson, Rollo and Clover Docks, Ltd., at Birkenhead BELOW is for repairing ships up to 65,000 tons deadweight ; it is 800ft long by 120ft wide with 28ft 8in depth on the sill at M.H.W.S. It has a " Box " gate with provision to impound water up to a maximum reverse head of 16ft, by the incorporation of stops in the sill and hydraulically-operated locking bolts in the jambs.

The dock can be filled in two hours. The filling culvert is built into the sill and discharges water, free from turbulence, at a maximum rate of 700 cusecs through eight ports set in the face of the sill. Dewatering is completed in three hours by two 42in diameter axial flow vertical spindle pumps, and the final emptying and drainage is

Harbours

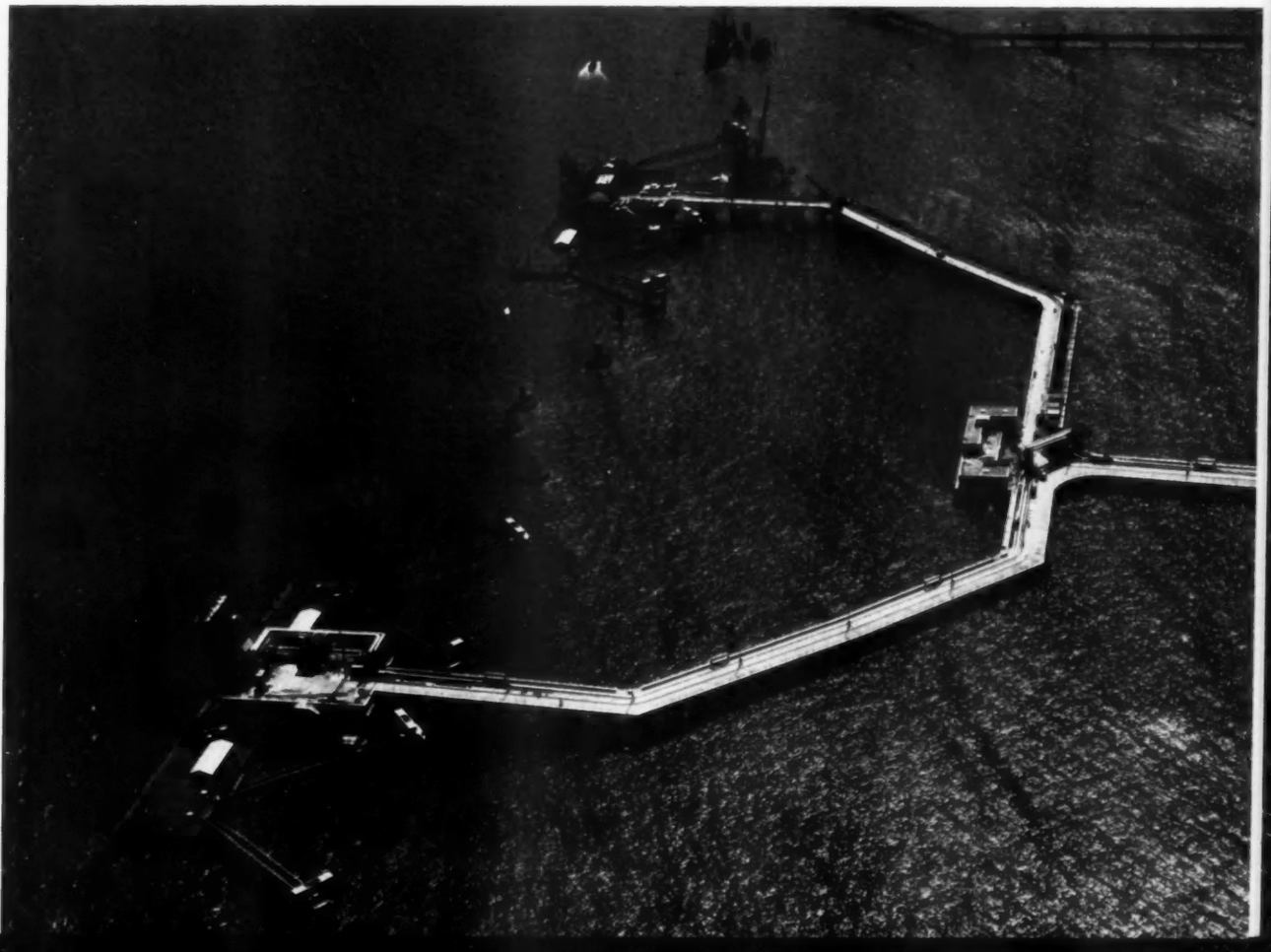
by two 10in diameter centrifugal pumps, also used for tank testing with the 5000 tons ballast reservoir built into the dock wall. Advantage is taken of the reversible properties of the main axial flow pumps to impound water towards the end of the filling of the dock.

Construction had to be carried out 150ft into the river. Walls of precast cellular concrete blocks, 10 tons each in weight formed part of the permanent work and were continued across the entrance in interlocking solid blocks to complete the cofferdam. The dock gate was built inside the cofferdam. Consultants, Sir Alexander Gibb and Partners ; main contractor, Marples Ridgeway and Partners, Ltd.

The Port of Tema ABOVE has been under construction since 1954, 15 miles east of Accra the capital of Ghana. Its cost is over £20,000,000 and the first stage is now almost ready for operation. It will consist of a main harbour of 400 acres ; 7000ft of quays ; 27 miles of railways ; a 20 acres commercial site ; a dockyard with a small dry dock ; and a separate fishing harbour. A new town is being built behind the port.

About 2,500,000 cubic yards of rock have been brought by rail from quarries 20 miles inland and placed to form the breakwaters, and over 3,500,000 cubic yards of rock and earth will have been moved to level the site and provide 110 acres of reclamation. The quay walls are of an unusual design which consists of a single thickness of 16-ton precast concrete blocks founded on rock and laid with a set-back at each course. An *in situ* capping block is 22ft wide by 10ft deep, and the wall stands 40ft high at a thickness of only 10ft. The blocks are laid as headers and are dry-jointed. Consultants, Sir William Halcrow and Partners ; contractors, Parkinson Howard, Ltd. ; Ackermann and Van Haaren.

Tranmere jetty, BELOW, to berth and unload 65,000 ton tankers, was designed for Shell by the Mersey Docks and Harbour Board ; main contractor, Peter Lind and Co., Ltd.; stages and mooring dolphins, Cleveland Bridge and Engineering, Ltd. Vertical movement of 60ft between tanker and quay is allowed for, by using two floating stages, each 362ft long, and twelve floating mooring dolphins. The floating elements are held by steel tubes grouted into 30ft holes in the sandstone rock on the river bed. The tubes are 5ft 5in in diameter and up to 120ft long ; each one can resist a horizontal pull of 150 tons at high water. Each dolphin has one such tube at its centre, and each stage is held by two pairs of 150ft booms. The booms are each anchored by a pair of tubes, through a pivoted suspension with 100-ton ballast boxes such that the stage becomes a floating gravity fender. The approach jetty is of reinforced concrete.



Evening Star

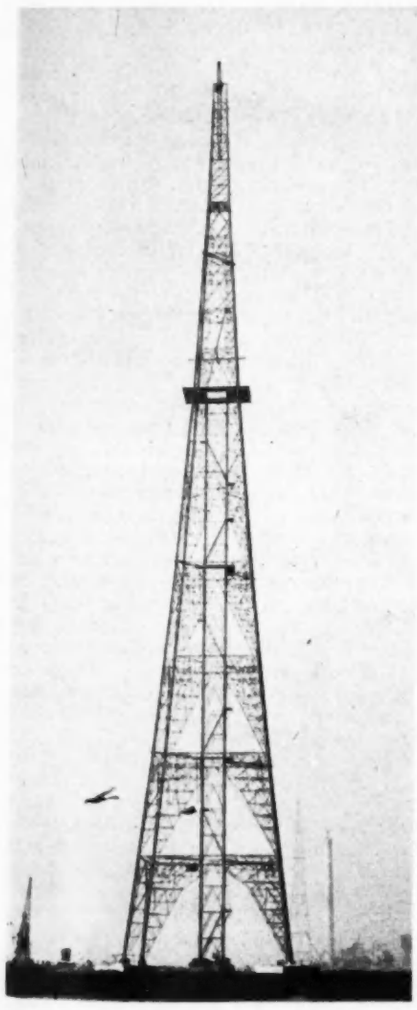
Coal and railways were two great factors stimulating the industrialisation of Britain in the nineteenth century. Both were typified by the steam locomotive. Now there are other sources of energy, and although coal remains of great importance, it no longer has a monopoly, and newer sources of energy show promise of growing in importance. The railways too have been ousted from their position as the backbone of land transport, and are now the junior in the partnership of road and rail. Amongst the factors involved in these changes has been the obsolescence of the steam locomotive. In the two pictorial supplements reviewing 1960 the emphasis has naturally been on new developments, and on trends stretching towards the future. Here we pause ; our illustration depicts an achievement of 1960, but one which is already of historical significance, rather than exemplifying the technical advance we have tried to stress elsewhere.

For many years illustrations of steam locomotives have provided an outstanding feature in the first January issues of " The Engineer " and we can safely claim that an illustration of every class of steam locomotive built in this country has appeared in our pages. It is with a feeling of regret, therefore, that this year we have to show the last of the " iron horses " to be built in the shops of British Railways. This class 9, ten-coupled, freight locomotive was built at the Swindon works, where so many of its famous predecessors originated, and was aptly named " Evening Star "—for it marks the end of a great era in railway history. No engineer looking at such a locomotive " in steam " can but be impressed by its majestic dignity. When, in a few years, the steam locomotive no longer serves on our railways, what for more than a century has been an intrinsic part of British engineering will have yielded its place to more modern techniques.

West Thurrock Supergrid Crossing of the Thames

An important part of the 275kV supergrid being installed in Southern England by the Central Electricity Generating Board is the crossing of the River Thames between West Thurrock and Northfleet, which has entailed the construction of two 615ft high towers. These towers, of high-tensile steel, support the conductors spanning 4500ft giving a minimum clearance of 250ft between the lowest point of the span and the mean high water level. Two 145ft anchor towers, also of high tensile steel, take the strain of the crossing conductors.

THE West Thurrock crossing of the River Thames is one of the major stages in the development of the 275kV supergrid of the Central Electricity Generating Board in Southern England. It provides an essential part of the continuance of the supergrid into South Eastern England and will also form a major step in the closure of the 275kV "ring" around London. The new line, of which the crossing forms a part, starts at the C.E.G.B.'s 275kV station at West Thurrock on the North bank of the Thames and is carried over to Northfleet before continuing as a standard 275kV line via Canterbury to Lydd with connections to the Cross-Channel cable link and to the nuclear power station now under construction at Dungeness. Its design and erection has taken account of the Board's recently announced policy of uprating the supergrid from 275kV to 400kV, a policy which has been adopted in order to increase transmission capacities and to minimise the number of grid lines required, thus reducing interference with amenities to a minimum. In essence, the crossing consists of two 615ft towers of high-tensile steel which support the conductors at the necessary height to gain the stipulated river clearance, and two anchor towers which take the strain of the crossing conductors. We reproduce some photographs taken of the towers during their construction.



615ft high tower for the supergrid crossing of the Thames

The selection of a site for the crossing and the consideration of the most suitable design for both towers and conductors was the subject of extensive studies by the transmission line design engineers of the C.E.G.B. Due to the special position of the Board in the U.K. with regard to the generation and transmission of electrical power, the Board's staff fulfils a consulting role, drawing up the overall design parameters, investigating and supervising detail design and construction. In considering the design factors for the crossing, it was apparent at an early stage that the site between West Thurrock and Northfleet was the most suitable for this crossing. It was also obvious that, due to the 4500ft of the span and the fact that a minimum clearance of 250ft between the lowest point of the span and the mean high water was required by the P.L.A., special attention would have to be given to the conductor tower design.

The standard conductors which the C.E.G.B. employs for the 275kV supergrid are twin 0·4 square inch steel-cored aluminium conductors per phase. As these conductors would not provide sufficient strength for the 4500ft span of the crossing there was developed a 199-stranded, steel-cored conductor, using 91 tons to 120 tons per square inch steel wires as a core with 108 strands of aluminium arranged in three layers over the core. This conductor matches in capacity the twin conductors of the incoming lines and has sufficient diameter (2·262in) to accommodate the maximum operating pressure of 400kV without corona losses arising. Its high mechanical strength necessary to obtain an economic sag, is shown by the calculated ultimate strength of 290,000 lb, and the modulus of elasticity at $14{\cdot}25 \times 10^6$ lb per square inch, the maximum working tension being 97,200 lb. In working out the design, account was taken of aerodynamic effects which might be expected with long spans of this nature, in addition to the more routine meteorological aspects. The design radial thickness for ice loading is 0·5in and the wind loading figure on 80 per cent of wind span is 15 lb per square foot.

A central over-running earth wire of the same construction as the conductors will be employed on the crossing. This wire will give a shielding angle of 45 deg., and by using a conductor for this duty, uniform mechanical characteristics and economic life are obtained together with a measure of convenient interchangeability. The conductors were manufactured by British Insulated Callender's Cables, Ltd.

The two 615ft high crossing towers are square in plan, the base being 100ft square. The overall lengths of the top cross-arms are 74ft. Each tower consists of twenty-one main leg sections, between 25ft and 31ft in length and making eleven panels. The five lower panels take the form of modified "K" bracings, and they are followed by a series of open diamond and scissor braced panels. The shape of the tower is governed by a change of leg slope at every second panel, i.e. every 125ft ; it was both convenient and desirable to use such an interval to enable aircraft obstruction lights to be sited at the main horizontal bracing members at these levels, thus also providing supports for the access catwalks to the lights.

Top section of a crossing tower, showing conductor cross-arms and maintenance platform

At the top of the third pair of panels (375ft) is located the main maintenance platform which will carry an overhead track and trolley together with winching equipment used for lifting and assembling spare insulators. Further maintenance lifting gear, at the top of the tower, is supported by a special cross-arm located above the topmost conductor cross-arms. Enclosed within each of the towers is a 15ft square central column which extends up as far as the 375ft maintenance platform. These columns were included in the design to assist in the erection of the six lower panels of the towers by providing a base for the derrick

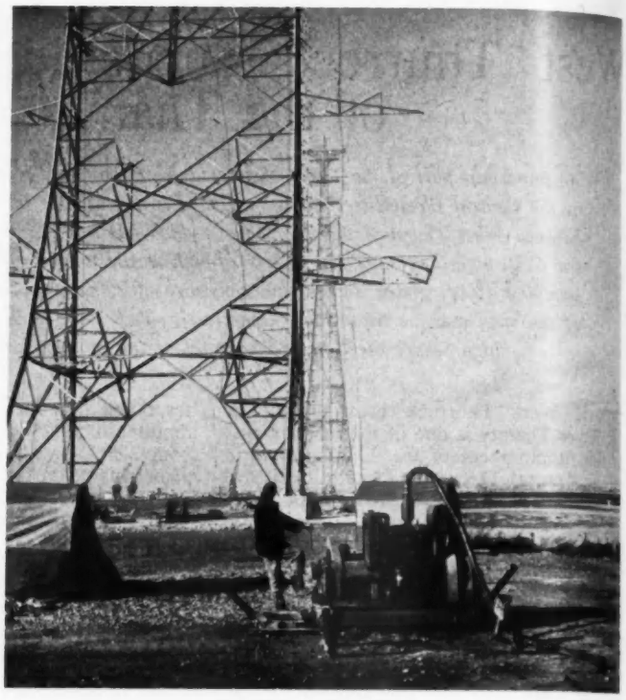
and also to give a structure around which a central stairway could be built of standard units, with radiating catwalks out to the aircraft lighting panels. The columns also form central lifting wells for maintenance material and equipment. The tower steelwork comprises standard, galvanised, high-tensile steel rolled sections conforming to B.S. 548. Each tower was assembled on site and of particular note has been the smoothness with which site assembly proceeded, resulting from the observance of extremely fine tolerances in manufacture.

The anchor towers, also fabricated from high-tensile steel, each consist of four panels with heights of 30ft, 41ft, and 33ft, each panel forming an open diamond structure. These towers function as frames to which the crossing conductors are secured. They are also provided with three pairs of auxiliary cross arms which support the " jumpers " or connections between the incoming lines and the crossing conductors. The detail design of both crossing and anchor towers was carried out by Blaw Knox, Ltd.

Mounted at the end of the suspension tower cross arms are universal bearings from which the insulator assemblies are hung. These insulator assemblies, manufactured by Bullers, Ltd., have jacking equipment to allow the insulator strings to be removed for servicing, and inspection of the universal bearings will also be possible without disturbing the insulators. The suspension assemblies on the crossing towers consist of six insulator strings in parallel, and the tension sets have eight parallel strings, all the insulator assemblies incorporating lever balancing between strings and being designed for equal load sharing in the event of one string failing. Each string consists of twenty porcelain units in both the suspension and tension sets, two extra units being fitted to each tension set to improve the wet flashover values. The diameters and centres of the porcelain units are 14in by 6¾in in the suspension sets and 12¾ in by 7¼in for the tension sets, the overall lengths being 275½in and 294¾in respectively. Ball and socket insulator couplings are used throughout. The ultimate load figure for the suspension sets is 180,000 lb, whilst that for the tension sets is 240,000 lb.

The foundations for the towers were started on both sides of the river early in 1959, and tower construction commenced in August, 1959. The foundations for the crossing towers consisted of thirty 17in square reinforced concrete piles at each of the four legs of the tower, and at the anchor towers 100 piles are provided at the rear to resist overturning forces. The piles were driven to a depth of 40ft on the North side and 45ft on the South bank. The survey work in connection with setting out the towers was particularly intricate, and all four towers are aligned to within ¼in over a total length of 7700ft. The spans were checked with a geodetic theodolite, a tellurometer being finally used to check span distance over the 4500ft to within 3in. The exceptional accuracy of alignment was obtained by mounting neon tubes vertically on masts at each site and aligning these tubes at night-time by theodolite observation under V.H.F. radio control.

The building of each crossing tower by British Insulated Callender's Construction Company, Ltd., began with the erection of the first 125ft of the central column and upon this an 80ft derrick was mounted in a lifting rig for the erection of the first 60ft panel of the tower. When this panel was complete the central column was erected another 60ft, the luffing derrick was also lifted up 60ft, and erection was continued on the second panel of the main structure. Above the 350ft level this derrick was used as a floating rig for the main construction. The structures were assembled with G.K.N. high-tensile bolts using ratchet spanners.



Hoisting anchor tower steelwork

The winching duties for raising men and components at the crossing towers was carried out by a modified Sykes No. 8 winch powered by a Lister F.R.4 engine. A further Sykes No. 7 winch powered by a Ruston 3YC engine was provided as an auxiliary on each tower. The main winch used was reeved on a 3 : 1 reduction tackle, the maximum bond length being 4100ft ; the drum speed of 120ft to 150ft per minute gave a lifting speed of 40ft to 50ft per minute. The bond used was ½in diameter steel wire rope in ten laps. The main winch used at the anchor towers was a Sykes No. 7, the auxiliary being a No. 6 size. This main winch was reeved as at the crossing tower and a maximum lift of of 3 tons was required for the top main truss. A 3000ft bond length was provided with this winch to enable it to be used for lifting the insulators of the main tower. Of particular note are the safety brakes used with the winches to guard against any mishap should the winch operator be suddenly incapacitated, as for example in the event of an electrical discharge down the tower and along the bond. The safety brakes employed are normally in the applied position and are released by pedal operation.

The most intricate part of the construction of the crossing towers was the erection of the top maintenance crossarm, which required an additional derrick at the 600ft level. The crossarm was erected, section by section, 615 above the ground, early sections being stayed. When this unit was completed, the six lower insulator crossarms were raised into position. These crossarms each weighed 2½ tons and they were pre-assembled on the ground.

The running of the conductors also presents certain facets of interest. This procedure will consist of laying a track rope and a haulage rope in the river, with each end passed over the tops of the crossing towers on wheeled paddles. At times agreed with the P.L.A., the river will be closed and these ropes will be hoisted out of the water and tensioned by winches and tackle at the rear of the anchor towers. The haulage rope and track rope will then be " stitched " together by a set of trolleys which run on the fixed track rope and are pulled by the moving haulage rope. When the system is completely coupled and ready, it will carry the conductors by means of a further set of suspension trolleys which will be hauled over the crossing, the suspension trolleys being fed on at one end and the stitching trolleys being removed at the other end. The conductor drum will be mounted on the North bank and the haulage winch on the South bank. For this work all operations will be directed by V.H.F. radio control and six radio sets will be used to maintain contact between the teams on the ground, at the tower top and on the opposite side of the river. One of the conditions of the contract is that no conductor shall touch water or land at any stage. As each conductor is received across at the far anchor tower, it will be tensioned at both ends and released from the suspension trolleys; this is possible as the sag of the track rope system will be greater than the sag of the conductor in its service position. Tension and suspension insulators will then be inserted at the anchor and crossing towers and the track rope and trolley prepared for the next conductor by reversing the haulage rope, re-attaching the stitching trolleys and recovering the suspension trolleys at the North bank anchor tower.

The main contractor to the C.E.G.B. for this work is the British Insulated Callender's Construction Company, Ltd., the detail tower design being by Blaw Knox, Ltd. Steelwork for the suspension towers was fabricated by Horsley Bridge and Thomas Piggott, Ltd., whilst that for the anchor towers was fabricated by Painter Brothers, Ltd. The foundation design consultants were Sir Alexander Gibb and Partners, the foundations being placed by Holloway Brothers, Ltd., and Mears Brothers, Ltd. The conductors are being supplied by British Insulated Callender's Cables Ltd., and the conductor erection equipment by John Barnsley and Co., Ltd. The anchor clamps, armour rods and vibration clampers are supplied by Alcan Industries, Ltd.

Shipbuilding and Marine Engineering in 1960

No. II—(*Continued from page 22, January 6, 1960*)

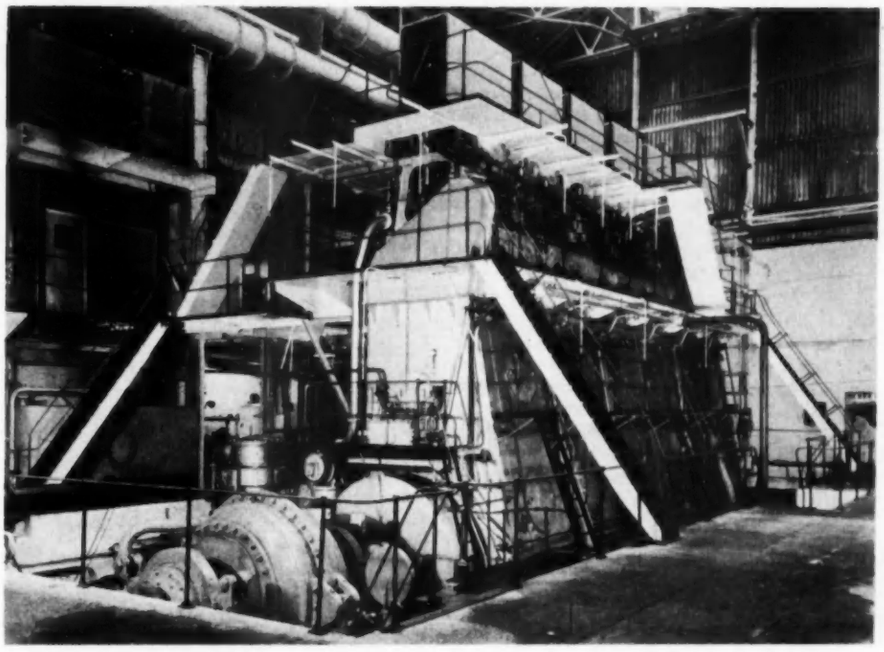
Research and Development

TOWARDS the end of the year just completed there was considerable discussion and criticism of the scientific status of the shipbuilding and marine engineering industries and their associated research associations. Much of this was initiated as the result of the premature disclosure in October of the contents of the draft of a report, prepared by the Department of Scientific and Industrial Research and based on an investigation of the industry by that body. Following discussion of the draft between the industry and D.S.I.R. an agreed final version of the report was issued in December. This is an interesting document which is not altogether lacking in constructive comment, at least with regard to those criticisms of the adequacy of the industry's research associations which apply to the British Shipbuilding Research Association. Many of these criticisms were answered in the statement made by Sir James Milne at a general meeting of the Association held on October 6. He recalled that the current terms of grant aid are £60,000 per annum from D.S.I.R. to £300,000 from the industry and pointed out that expenditure for 1960–61 was estimated to increase to £435,000 compared with £330,000 in 1959–60, and £277,000 in 1958–59. These figures indicate the steady progress made in research programmes but the expansion of the Association's activities would have been more heavily emphasised if Sir James had mentioned that the expenditure level was £127,000 in 1949–50, and £193,000 in 1954–55.

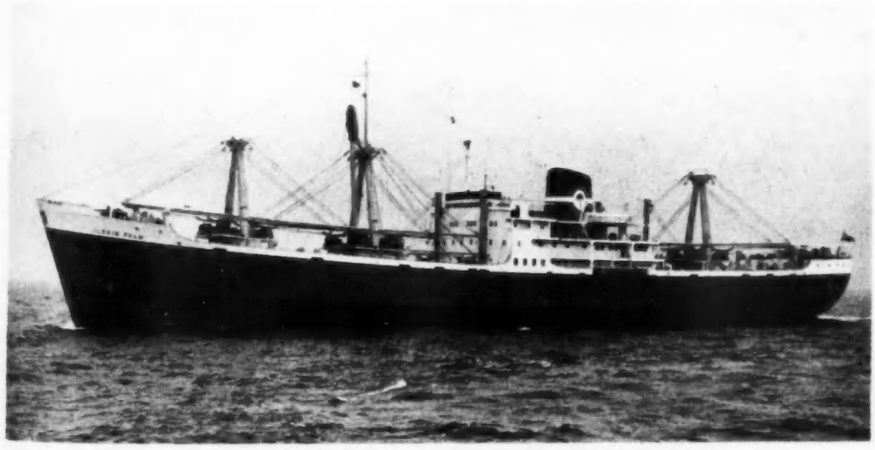
The expansion taking place is further underlined by the removal of the Association to more commodious accommodation at Prince Consort House, on the Albert Embankment, overlooking the Thames. This move was made essential by the overcrowding of the original headquarters coupled with the need to house the additional staff required to carry out existing research programmes on a greater scale, and to undertake new projects. The statement made by Sir James also served to correct a widely held misconception that the work of B.S.R.A. is mainly carried out under contract at laboratories outside its control, the cost of extramural research being approximately only one-third of the total. A substantial contribution is also made by the B.S.R.A. staff who carry out full-scale investigations on ships and engines, deal with building and launch problems, and attend trials both on the test bed and in service at sea. In the field of vibration, for example, readings have been taken on over 100 ships, sometimes involving many visits to a particular ship in order to take a full range of readings. In certain trials the B.S.R.A. exciter has been used to artificially set up vibrations. From subsequent analysis of the various readings it had been often possible to put forward an effective remedy, but of much greater importance it is that with the aid of the accummulated data it has been possible to predict more accurately vibration characteristics at the design stage. It is due to the availability of this knowledge that many new ships are free of vibration troubles.

The potential value of computers to shipbuilding is well recognised by B.S.R.A., and in earnest of this it has formed a section to deal solely with this subject. As a first step it is intended to review the computer facilities available for ship design calculations together with their programme capacity. Furthermore the Association proposes to be financially responsible for assistants, at Glasgow University and King's College, Newcastle upon Tyne, to assist in the preparation of programmes and in their operation through the computers. Work directed at formulating mathematical equations for ship's lines is already in hand at various centres, and B.S.R.A. has set up a committee to coordinate and compare programmes and to fill in any gaps. Later it is hoped to deal with design calculations and success in this may lead to the use of computers for production processes, such as computer controlled flame cutting machines, provided that the developments improve efficiency and offer financial advantages.

Another development significant to the future of the industry and a logical continuation of previous studies was the setting up of a production and operational research organisation. It is understood that B.S.R.A. staff will undertake production research



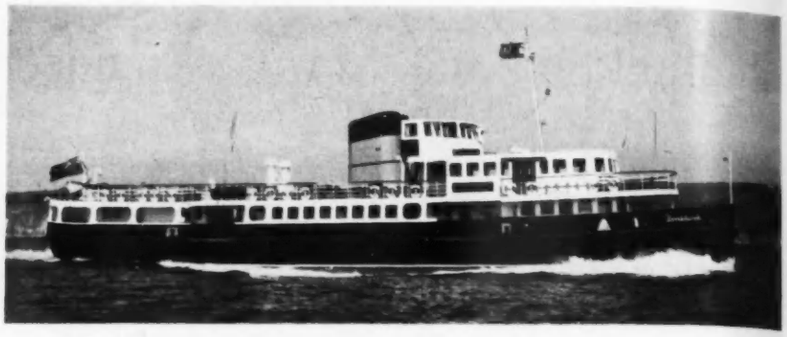
Advances in design resulted in the production of the Doxford "P" range of engines, of which our illustration shows a mark 67 P.T.6 unit on the test bed. The range consists of a 560mm bore by 1750mm combined stroke turbo-charged engine having a power range of 4120 to 6990 b.h.p.; 670mm bore by 2100 combined stroke normally aspirated and turbo-charged units with a power range of 3210 to 10,000 b.h.p.; and a turbo-charged engine having a bore of 850mm by 2500mm combined stroke and developing 10,400 to 18,000 b.h.p.



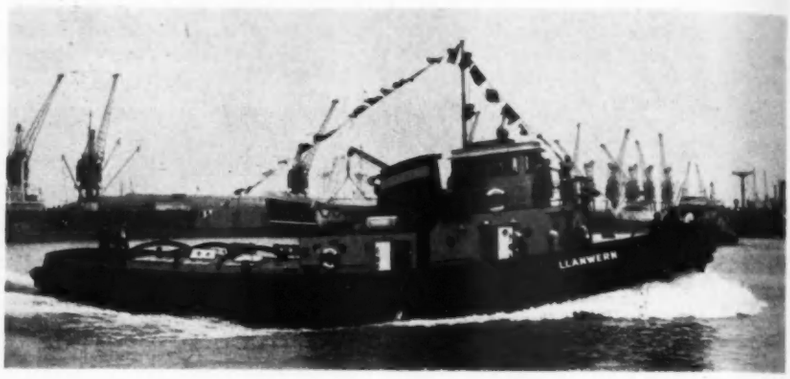
Built at the Neptune Works of Swan, Hunter and Wigham Richardson, Ltd., for the Palm Line, Ltd., the "Ilorin Palm" carries a deadweight of 8950 tons on 25ft 1¼in draught and the following dimensions; length between perpendiculars 430ft, breadth 62ft 6in, and depth to shelter deck 36ft 11in. There are five holds, three bipod masts, a complement of one 50-ton, four 15-ton, two 10-ton and ten 5-ton derricks and sixteen electric winches. Three 250kW diesel-driven generators provide electric power and propulsion is by a Swan, Hunter-Doxford oil engine having five cylinders of 670mm bore by 2320mm combined stroke, burning boiler oil and developing 4500 b.h.p. at 118 r.p.m.

Smaller Craft

Philip and Son, Ltd., completed the twin-screw Mersey passenger ferry "Woodchurch" for the Birkenhead Corporation. She has a Steam 5 certificate for 1200 persons. The ferry has a length between perpendiculars of 142ft 6in by 39ft beam by 12ft 6in depth and a load draught of 7ft 3in. Steering is by twin balanced rudders and propulsion is by two eight-cylinder Crossley H.R.N. diesel engines, each developing 680 b.h.p. at 350 r.p.m. Trial speed 12·6 knots.



The diesel-electric tug "Llanwern" was built by P. K. Harris and Sons, Ltd., for service at Newport Docks, and has the following dimensions: length between perpendiculars 85ft, breadth moulded 25ft 9in, depth moulded 11ft 9in, and gross tonnage 160. Propulsion machinery consists of two eight-cylinder Lister-Blackstone diesel engines, each developing 660 b.h.p. at 750 r.p.m., each coupled to a Brush generator, and two Brush motors, of 550 b.h.p. at 1250 r.p.m., driving through Hindmarch-M.W.D. single-reduction gearboxes to give a speed of 12 knots. With one engine the running free speed is 10 knots and the bollard pull 10 tons.



John I. Thornycroft, Ltd., built the tug/tender "Gatcombe" for the Southampton, Isle of Wight and South of England Royal Mail Steam Packet Company; she carries 200 passengers and six cars as a tender or 400 passengers on passenger work only. The ship measures 136ft length overall by 32ft beam by 14ft 6in depth, and has a gross tonnage of 512·9, a pull of 20 tons and a free speed of 12½ knots. Electric power is supplied by three 50kW diesel-driven generators, while for propulsion there are two eight-cylinder Crossley H.G.N. two-stroke diesel engines, each developing 900 b.h.p. at 450 r.p.m. and driving through a Hindmarch-M.W.D. reverse reduction gearbox.

The middle water trawler "Barnsley" completed by the Goole Shipbuilding and Repairing Company, Ltd., has accommodation for a crew of nineteen. The dimensions are 137ft 3in length between perpendiculars, 28ft breadth moulded and 14ft 3in depth moulded. The fish room has a capacity of 11,000 cubic feet. A 175 b.h.p. electric motor, supplied with power by a 146kW generator driven by a Mirrlees diesel engine, drives the Robertson trawl winch which is able to take 1200 fathoms of 2¾in warp on each barrel. Propulsion is by a Mirrlees Mark KSSD.M.8 four-stroke, single-acting supercharged diesel engine delivering 1120 b.h.p. at 270 r.p.m. On trial a mean speed of 12·96 knots was obtained and the ship has a bunker capacity, and a fresh-water storage capacity sufficient to give an endurance of thirty-five days.

Hawthorn Leslie (Shipbuilders), Ltd., completed to the order of the Warwick Tanker Company, Ltd., the 35,530 tons deadweight tanker "Brandon Priory" which measures 683ft length overall by 86ft beam by 49ft 3in depth. Oil cargo is carried in thirty tanks and propulsion is by a single set of double-reduction geared turbine machinery, of 14,000 service s.h.p., supplied with steam at 600 lb per square inch and 850 deg. Fah. by two Foster Wheeler E.S.D. water-tube boilers. Two 600kW, 440V, 60c/s turbo-alternators provide electrical power

resulting from the work of the new organisation. This development matches similar activities by other associations and renders nugatory the suggestion that the awareness of the importance of such research by British shipbuilding is less than it should be.

Quiet and unspectacular progress describes the developments in nuclear propulsion and tenders for such machinery called for by the Government and based on particular reactor technologies called for study by "Numarcom." Reports were prepared and circulated to member firms of the studies made in the U.S.A. of the N.S. "Savannah," and members of the nuclear energy team continued to work at the Riseley and Winfrith establishments of the Atomic Energy Authority. While assisting with research projects at Winfrith the team also examined the possibilities of a high temperature gas-cooled graphite moderated reactor and thought that this technology showed promise. Staff loaned from member firms formed part of the team and were replaced by others, after a period, so that many men have been trained and provide a reservoir of training and experience, related to marine nuclear engineering, ready to be used for the design and construction of nuclear ships.

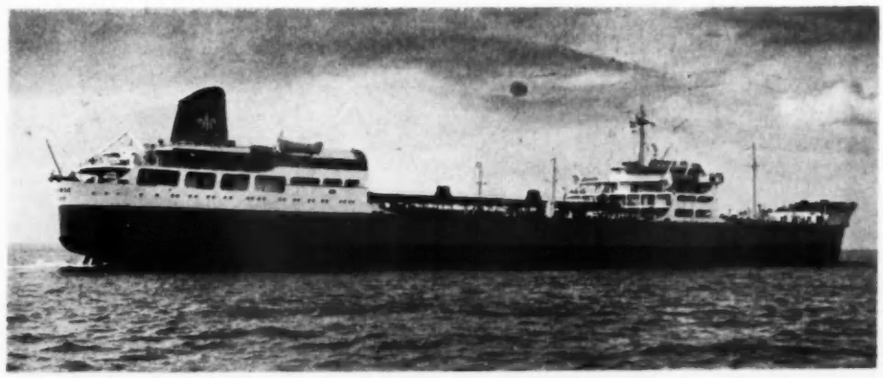
In the methodical series work proceeded on models having block coefficients up to 0·85, but before deciding upon the design of the present form it was found necessary to study the problems of turbulence stimulation and afterbody flow separation set by a form of this fulness. Tests were also put in hand to measure the effect of four forms of bulbous bow and also three different shapes of afterbody sections using a systematic series of forms having a block coefficient of 0·80. The report was in preparation of the programme on the methodical series of trawler forms, including resistance charts for design purposes. Further work planned for this series is a study of the effects of bulbous bows and special sterns. Statistical roll records were taken on similar oil tankers, one with and one without bilge keels, and further work on the problem of scale effect is to be considered by the Hull Sub-committee. As a result of a questionnaire circulated to owners and builders it was made evident that there was a need for scientific data to assist in obtaining rudder areas and torques, and this matter was taken in hand. In the wider field of hydrodynamics, representatives of B.S.R.A. attended the International Towing Tank Conference which was held in Paris in September.

During the year work continued in the accummulating of stress data, several ships being fitted with recording stress gauges. In the course of three transatlantic voyages of the "Cairndhu," as part of the Association's sea keeping investigations, detail stress measurements were obtained and are of particular value as sea states are being measured during trials. The structural behaviour of deckhouses and superstructures as part of the strength girder has received attention over many years, and last year the stresses in a superstructure of aluminium alloy were measured during the launch of a passenger liner. The readings indicated that superstructure was about 80 per cent efficient in its contribution to the longitudinal strength of the ship girder. As part of the corrosion investigation of the structures section, a questionnaire was sent to shipbuilders and owners to gather data upon both the extent and severity of corrosion in ships. In this work B.S.R.A. co-operates with B.I.S.R.A., and the latter set up an *ad hoc* panel to investigate corrosion problems in confined spaces or those difficult of access, with particular reference to double bottom compartments in which water ballast alternates with oil fuel. At Glengarnock the programme of tests on swedged plating and on comparison panels of plating having flat bar stiffeners was continued, as was the work on bracketless knee connections. With regard to the buildings at Glengarnock, Colvilles, Ltd. undertook to modify the sheds housing the testing machine and to extend that containing the new machine to provide a bay to house the old machine. This arrangement enables lifts and hoists to serve both machines and facilitates the handling of specimens. At the same time better office accommodation has been provided for the Lloyd's staff, who man the station for B.S.R.A., to enable the establishment to be operated more efficiently.

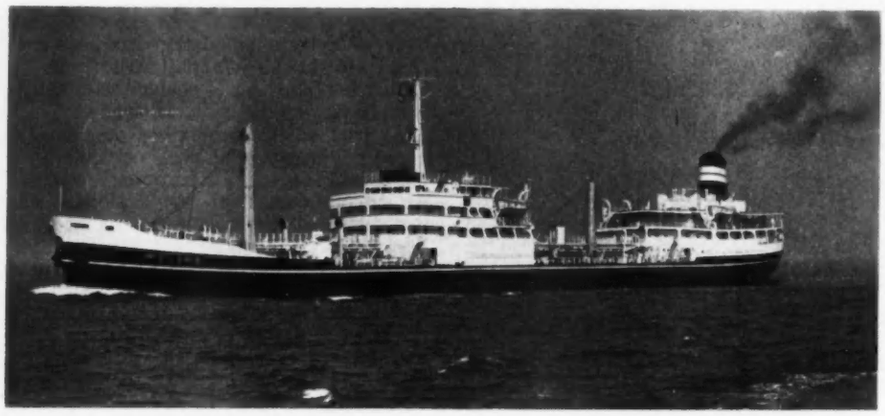
As part of the programme to develop improved sound insulation, particularly in passenger liners, member firms were requested to submit details of the materials and methods used in the construction of bulkheads in accommodation. From the information so obtained a survey is in course of preparation on the construction of single and double partitions. Vibration measurements continued to be carried out on ships, and investigations into the added virtual mass and the vibration of ships' plating were nearly completed.

To the machinery research programme concerning scavenging and supercharging of marine two-stroke engines were added investigations to cover: the thermal loading of such engines; the possibility of improving turbo-charger efficiency; the effect of a small number of stress reversals at high stress levels upon the strength of particular steels and cast irons; and the potentialities of the plasma-arc surface hardening technique in the industry. These items were made a matter of urgency and it was arranged to have assistance from outside organisations having specialised knowledge of the particular research items. The forces and stresses in steam pipes at elevated temperatures were measured on a three-dimensional system, and a project put in hand to take readings in service. Noise measurements were made of free-piston gas-generator machinery, and progress made in the investigation of the laws of natural circulation in water tube boilers. Vertical tubes were dealt with, and the development of the use of radioactive isotopes to measure density of the steam-water mixture enabled the second phase of the work, that dealing with inclined tubes, to go forward. An examination of the heating of heavy oil in a scale model of a cargo oil tanker was completed, and a study started of the effect of varying rates of heating and of the distribution of heat losses.

An ultrasonic method of measuring torsional rigidity of propeller shafts was developed and will enable calibrations to be made while at sea. Furthermore, a transient torque recorder was developed, and the possibility of measuring transient thrusts received attention. To extend the measured mile trial code of procedure to include the large deadweight oil tankers now being



Radcliffe Tankers, Ltd., took delivery of the "Llangorse" which was built by the Furness Shipbuilding Company, Ltd. The main dimensions are: length between perpendiculars 640ft, breadth 85ft, depth 46ft 7in, draught 34ft 5½in and deadweight 33,100 tons. There are thirty cargo oil tanks and the oil is handled by Hayward Tyler 1600 tons per hour pumps and two J. P. Hall 200 tons per hour stripping-pumps. Two 425kW turbo-generators supply electrical power and the propelling machinery consists of one set of Wallsend Slipway double-reduction geared turbines of 11,000 normal s.h.p. and supplied with steam at 570 lb per square inch and 880 deg. Fah. by two Babcock and Wilcox "Selectable Superheat" boilers



The 19,000 tons deadweight tanker "Quiloa" was built and engined by Scott's Shipbuilding and Engineering Company, Ltd., for the British India Steam Navigation Company, Ltd. The deadweight is carried in a draught of 30ft 2in and the following dimensions : 534ft length between perpendiculars, 71ft 8in breadth and 39ft 6in depth. Twenty-seven tanks take the cargo and the power for auxiliaries is provided by two 550kW turbo-alternators while propulsion is by double-reduction geared turbines developing 8000 s.h.p. at 100 propeller r.p.m. and giving the ship a service speed of 14·5 knots.

built, a programme of acceleration and stopping trials using a 50,000 tons deadweight tanker was put in hand so that the length of approach required to attain full speed on the mile may be deduced.

Progress was made with analysing the recorded sea-keeping data, which was in punched tape form and fed directly into an electronic computer. This sea-keeping investigation requires a considerable amount of time since it is necessary to wait until the weather and sea conditions are correct for a particular research purpose. A start was made with the preparations for the trials to be made on the research trawler "Earnest Holt," and as a result of previous experience B.S.R.A. is preparing a specification for a revised system of sea-keeping instrumentation. At the British Exhibition held in New York in June B.S.R.A. took part in the exhibit organised by the Shipbuilding Conference on behalf of the British Shipbuilding Industry and showed a research exhibit, and also produced a special brochure on ship research.

According to the latest progress report available concerning the activities of the Parsons and Marine Engineering Turbine Research and Development Association, twelve reports were issued to member firms and one contract report prepared for the Admiralty, while thirteen contract reports were completed for individual firms. Four provisional patents were applied for in this country and five in seven other countries, and in addition sixteen full patents were granted to the Association in eight countries. To provide adequate steam supplies for test purposes a Babcock and Wilcox boiler and associated plant has been installed, and is specified to produce 264,000 lb per hour of steam at maximum output. Of this quantity, 200,000 lb per hour of steam at 1200 lb per square inch gauge and 1200 deg. Fah. will be available for testing purposes, while higher pressures will be available at a lower output.

Twenty-five sets of Pametrada designed machinery developing a total of 302,100 h.p. were installed, and one set returned a fuel consumption of 0·50 lb per shaft horsepower per hour using steam at 780 lb per square inch gauge and 858 deg. Fah. and a vacuum of 28·8in. Some sixty-three specific design enquiries were dealt with and ranged from 700 to 65,000 s.h.p. per shaft. A further seven enquiries concerned gas turbines to operate with free piston gasifiers, covering powers from 3000 to 8000 s.h.p. Work continued on the design of reversing inward radial flow gas turbines having single and two stages, and a study was undertaken of a turbine designed to use low pressure gas of very high temperature, the gas being expanded to sub-atmospheric pressure in the turbine while low temperature steam was admitted to cool the blades. A number of enquiries were received for conventional as well as hardened and ground reduction gears, and included a two-stage epicyclic gear to transmit 6000 s.h.p. The design department also studied the reheat cycle to assess the effect of cycle changes on turbine efficiency, and investigated the possibilities of the exhaust gas from a gas turbine being used as combustion air in a boiler.

In the research department work proceeded on the liquid cooled gas turbine, and in running the Mark 1 rotor the investigations were concerned with the heat flow conditions in the blading. One research item concerned noise reduction of machinery and involved the testing of two sets of gears, as hobbed and afterwards as shaved, and also the measurement of pipe noise. Other investigations concerned : single-stage and multi-stage air turbines, cascade testing in a supersonic tunnel, and combined disc and blading vibration tests. In the transmission section tests were continued on a third set of gears to compare the performance of a ground nitrided wheel with a case-hardened and ground wheel. The completion of one set of full scale gear trials was followed by another set in the same materials and tooth form, the pinion being in En 25, oil hardened and tempered to 55–60 tons per square inch, and the wheel in En 8, normalised and tempered to 40–45 tons per square inch, and the tooth form being 6in–10in pitch, 16 deg. pressure angle. The pinion-wheel addendum distribution ratio was 50-50 instead of 60-40, in the previous set.

Full scale rig tests on an hydraulic astern converter recorded an efficiency of 63·5 per cent at 3000 r.p.m., and the efficiency at full

Added to the fleet of the B.P. Tanker Company, Ltd., was the "British Curlew" which Alexander Stephen and Son, Ltd., built and engined at Linthouse. The principal particulars are : length between perpendiculars 495ft ; breadth 69ft ; depth 37ft ; service deadweight 14,000 tons on 27ft 6in draught ; service speed 14·5 knots. For the cargo oil there are twenty-seven tanks, two pump rooms and four 500 tons per hour pumps. The Stephen-Sulzer propelling machinery consists of a mark 7 R.S.A.D. 76 turbo-charged engine developing 8750 b.h.p. at 115 r.p.m. and with a mean effective pressure of 99 lb per square inch. Normal service power is 7750 b.h.p. Ships of similar size, the "British Mallard" and "British Gull", both built by Harland and Wolff, Ltd., also joined the B.P. tanker fleet.

Barclay, Curle and Co., Ltd., built and engined the "Athelqueen" for the Athel Line, Ltd., and the ship carries a deadweight of 19,800 tons and measures 560ft by 71ft 9in by 40ft 6in. There are two cargo pump rooms and nine sets of tanks, and three diesel-driven and one steam-driven generators each of 150kW. Propulsive power is developed by a six cylinder Barclay Curle-Doxford oil engine of 750mm bore by 2500mm combined stroke and fitted with a Bibby detuner.

speed of 3840 r.p.m. was estimated at 65·5 per cent at the design speed ratio. A standard Size 7 mechanised coupling completed endurance trials up to 7000 lb per foot torque at 5000 r.p.m., more than twice the rated loading, with a lateral misalignment of 0·070in before the coupling teeth were damaged. Another test was carried out under similar conditions but without lubricant and little damage to teeth was recorded. Attempts were made to measure the effective stiffness and effective mass of thrust block seatings by a dynamic method both on the laboratory scale and in a ship. Similar tests were carried out on a thrust block and the results indicated that the stiffness rate for the block increased as the load was applied. Pametrada shared with B.S.R.A. the stand at the British Exhibition in New York and displayed an hydraulic reversing transmission model, and also models of a single cylinder turbine and a set of tanker machinery.

(To be continued)

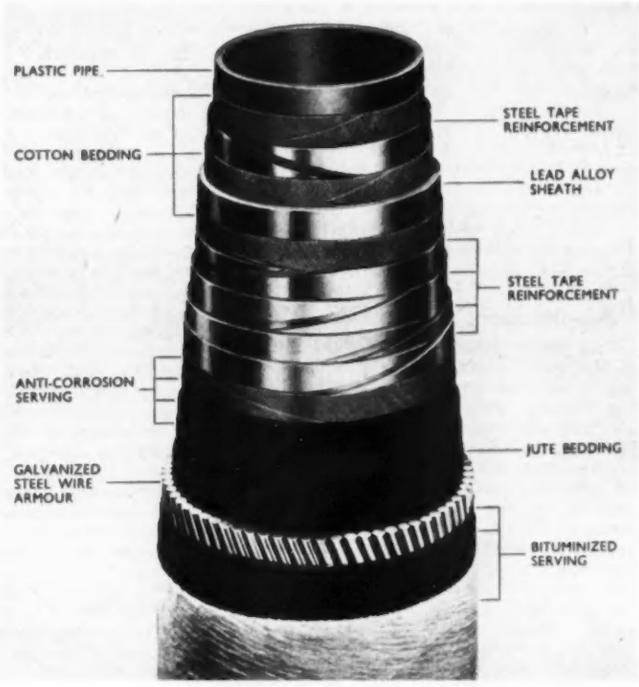
Flexible Submarine Gas Pipeline

IT was in 1956 that the British Insulated Callender's Cables Group completed the 138kV submarine power cable to link the lower mainland of British Columbia with Vancouver Island. Now the company is to return to the same area, having received a contract from the Magna Pipeline Company, Ltd., British Columbia, Canada, to manufacture, install and put into commission a flexible submarine pipeline to supply natural gas from the mainland to Vancouver Island. The contract, which is valued at 7,000,000 dollars, consists of twin pipelines having a total length of 53 miles and is intended to provide consumers on the island with the economic advantages presently available on the mainland. The operating company has been exploring the feasibility of transmitting natural gas, of which there were abundant supplies available on the mainland, to the potentially extensive market on Vancouver Island, and technical studies of the problems involved have been in hand over a number of years.

The success of the H.A.I.S. pipeline which was made for operation "Pluto" and was laid across the English Channel to carry petrol to France was due to its flexibility and ease of laying. The new pipeline is a development of the earlier pipeline and also of the supervoltage submarine power cable already referred to. H.A.I.S. pipeline principles have been embodied in the design and high-voltage cable making practice adopted for its manufacture. Furthermore, laying procedure will follow that used for submarine telegraph and electric power cables, and similar equipment be employed. Our sketch chart shows that the proposed route of the Magna Pipeline project crosses the Strait of Georgia, Galiano Island, the Trincomali Channel, Saltsprings Island and the Stuart Channel, and that rigid pipeline will be used for the land sections.

The general constructional details of the pipeline can be seen in our illustration. There is an extruded P.V.C. pipe having an internal diameter of 4·85in which is wrapped in helically applied steel reinforcing tapes in cotton bedding and then covered with a lead alloy sheath, followed by a further series of steel tape reinforcements. Over the latter are placed layers of anti-corrosion serving before the pipeline is armoured with galvanised steel wire over a jute bedding and then finally given a bituminised serving. The final external diameter is 7·5in and the pipe as completed has a weight of 51 lb per foot in air and 31·5 lb per foot in sea-water. The main advantage claimed for this form of pipe is that the smooth internal surface has a low coefficient of friction, much lower than that of steel, and when oil is conveyed the resistance to fluid flow does not tend to cause incrustation with paraffin wax. Tests carried out to establish the stability of the high impact plastic pipe have shown that it is extremely inert and resistant to aliphatic and low aromatic content hydrocarbons. Laying equipment is simple and long lengths can be laid at one time, while the couplings are easily fitted between lengths of flexible pipe. The strength of the pipe is such that it can withstand undersea currents, while its flexibility allows it to be laid on the sea bed without trenching.

The underwater section of the Magna Pipeline system, as planned, consists of two lines of flexible pipe, totalling 53 miles in length, laid adjacently, and each is required to transmit about 25,000,000 cubic feet of natural gas in twenty-four hours. This is equivalent to 750,000 h.p. or 560MW. At entry into the pipeline the gas will be at a pressure of 1500 lb per square inch and have a transit speed of about 14 m.p.h. and the corresponding values at the terminal point in Vancouver Island will be 500 lb per square inch and 42 m.p.h. The maximum depth of water in which the line will be laid is 810ft. British Insulated Callender's (Submarine Cables), Ltd., will manufacture the flexible pipe, which will be installed by British Insulated Callender's Construction Company, Ltd., while International Power and Engineering Consultants of Vancouver are the consultant engineers. It is planned to complete laying in 1963 after full scale sea trials in 1962.



Stepped sample of flexible submarine gas pipe to operate at a pressure of 1500 lb per square inch and at a depth of 810ft

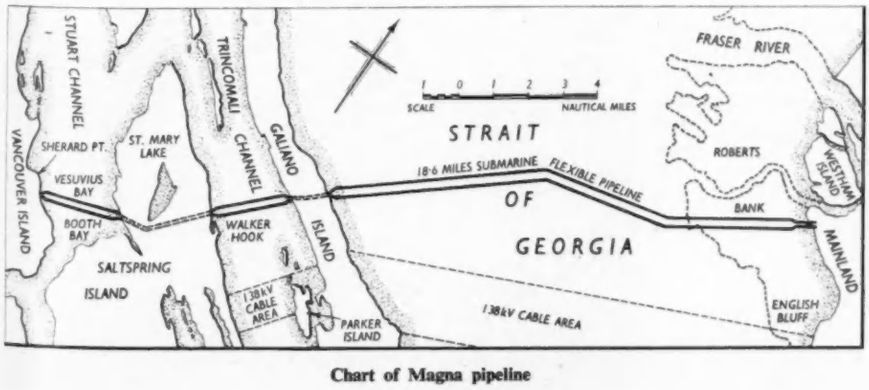


Chart of Magna pipeline

Miniature Capacitors

Two more capacitors of "Silver Star" fired construction have been developed by Johnson Matthey and Co., Ltd., 73–83, Hatton Garden, London, E.C.1. These new devices, A15E and A25E, are square in section, of very small size and designed specifically for transistorised printed circuitry. The components are encapsulated in synthetic resin. The A15E capacitor is ¼in square by ¼in long and has a capacitance range of 33–6000 μF (minimum tolerance ±2 per cent, or ±2 μF below 100 μF). A25E has the same section but is 1in long and has a capacitance range of 6000–20,000 μF (minimum tolerance ±1 per cent). Any capacitance value within these ranges can be supplied. Both types are rated at 50V peak working. Although the leads emerge axially, they can be adjusted to fit 0·1in or 0·2in module printed circuit boards. The square section permits the cementing of the capacitors to the printed circuit boards.

[Reply Card No. E552]

SHORTER REPORTS

Railway Modernisation Conference

AN account of what engineers have achieved to date in the modernisation programme of British Railways will be given at a Railway Modernisation Conference in London on May 3–4 this year. The conference is being organised jointly by the Institutions of Civil, of Mechanical, and of Electrical Engineers. It will be held at the Institution of Civil Engineers. Railway engineers from all over the world have been invited to attend. Five papers are being presented, namely :

" The Engineering Aspects of the Modernisation Plan for British Railways," by R. C. Bond, M.I.C.E., M.I.Mech.E. (Technical Adviser, B.T.C.).

" The Contribution of Civil Engineering to the British Railways Modernisation Plan," by M. G. R. Smith, M.B.E., B.Sc., M.I.C.E. (Chief Civil Engineer, Western Region, British Railways).

" The Impact of Mechanical Engineering on the British Railways Modernisation Plan," by J. F. Harrison, M.I.Mech.E. (Chief Mechanical Engineer, British Railways Central Staff).

" Electric Traction in the British Railways Modernisation Plan," by S. B. Warder, M.I.Mech.E., M.I.E.E. (Chief Electrical Engineer, British Railways Central Staff).

" British Railways Modernisation—Signal Engineering and Telecommunications," by J. F. H. Tyler, B.Sc., M.I.R.S.E. (Chief Signal and Telecommunications Engineer, Southern Region, British Railways).

" Mechanicals " Summer Meeting

THIS year's summer meeting of the Institution of Mechanical Engineers is to be held in Glasgow during the week commencing Monday, June 19. An informal reception by invitation of the Committee of the Scottish Branch will be held in the Royal College of Science and Technology on the Monday evening. The official opening of the meeting will be on the morning of Tuesday, June 20, and this will be followed by a technical meeting. In the afternoon alternative visits to engineering works and other places of interest have been arranged. There is to be a civic reception in the City Chambers by the Lord Provost and Magistrates of the City of Glasgow in the evening. Alternative visits to works and pleasure excursions have been arranged for Wednesday and Thursday, June 21 and 22, and the meeting will end with the Institution dinner and dance in the Central Hotel, Glasgow, on Thursday evening.

" Block-Release " Scheme for Apprentice Training

FOR many years Philips Electrical, Ltd., has recognised the importance of training youths for industry and maintained effective craft apprenticeship schemes based upon modern lines. An interesting departure from conventional training schemes was introduced late in 1958 at this firm's Croydon works when a " block release " system of part-time education for craft apprentices was started. Under this system an apprentice attends a technical college for sustained periods alternated with employment in the work's training school where he acquires practical workshop experience. This system has been found more effective than the generally adopted practice where a lad is released one day a week for study at a technical college and spends the remainder of his time on practical work. It was found that " day release " students tended to detach academic studies from practical training and often the academic standards attained were disappointingly low.

As distinct from craft apprentices, sustained study courses for students attending colleges for higher levels of education have been in use for some years. It was upon this practice that the " block release " system for the company's craft apprentices was developed. Under the scheme in practice new apprentices go first to the nearby Carshalton Technical College for three months before entering the works apprentice school, and during the first two years of apprenticeship spend two further three-month periods at the college. At the end of each of these three study periods the apprentice sits an examination which culminates in the City and Guilds Intermediate Examination in Machine Shop Engineering. In conventional " day-release " apprenticeship schemes the normal time taken for a youth to reach this standard is three years, under the " block release " system the same examination is taken in two years.

An additional advantage gained by the company with the introduction of the new system is that two groups of apprentices are being trained simultaneously—one group attending the college whilst the other is undergoing practical training in the company's training school. This has enabled the training staff to give maximum attention to each apprentice whilst at work by restricting the numbers employed in the school at any one time.

In designing and carrying out this " block release " system Philips Electrical, Ltd., has had the fullest co-operation of the Carshalton Technical Institute. The staff of the college has found the scheme both a help to students and stimulating to the teaching staff. At the end of the first two years of apprenticeship covered by the scheme the temperament and ability of each boy is assessed, and on leaving the works training school the boys are allocated to specific sections for further training as toolmakers, machine tool fitters, instrument makers or jig and tool fitters. In addition to training in these specialised departments the apprentices work for short periods in other associated sections of the works to broaden their general experience. During the shop training years each apprentice continues his academic studies on " day release " to enable him eventually to attain a Full Technological Certificate in Machine Shop Engineering issued by the City and Guilds Institute.

Prefabricated Tubular Steel Roofing

THE accompanying illustration shows the erection of a tubular steel roof in progress at Chesterfield, in which a system of roofing developed by Tubewrights, Ltd., was used. The building concerned is a factory 480ft long with an unobstructed width of 90ft. We are informed that "although work was spread over a number of weeks, the actual erection time taken for the framework, by only five men, was less than two days." Twelve " bays," each 40ft by 90ft complete, were lifted at each end by a crane and bolted into position after the roof framework had been bolted together on the ground. The new factory has been erected by Tube Construction (Bristol), Ltd., for S. and J. Kitchin, Ltd.

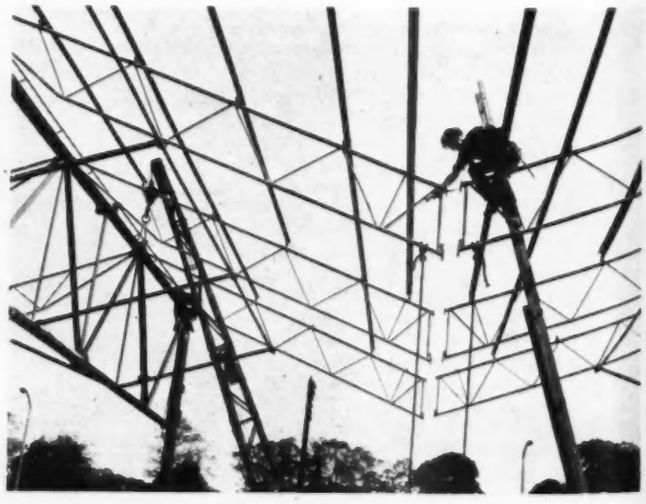
This structural system is made with two standard clear heights of 16ft and 20ft. The maximum column spacings are 45ft in one direction and 105ft in the other, although in certain long buildings this can be increased to 135ft. A service load can be carried on the roof steelwork. This load is generally 0·25 ton carried at each truss line along a girder, although when the 75ft and 90ft spine girders are supporting 40ft trusses, it can be increased to 1 ton. The spine girders and truss rafters are Warren-braced, the rafters being propped midway between the valley and apex. Gable and verge rails are carried off a standard truss. Erection bolts are standardised.

[Reply Card No. E564]

Oil Terminal at Cardiff

RECENTLY a new fuel oil terminal was opened by the Regent Oil Company, Ltd., at the Queen Alexander Dock, Cardiff, and it fulfils the dual function of providing ocean storage for fuel oils in South Wales as well as replacing the present light oil depot at Penarth. The terminal occupies a 12-acre site : Constructors John Brown, Ltd., carried out the detailed design and construction while Whessoe, Ltd., supplied and erected the storage tanks. Storage consists of six tanks, two each for light, medium and heavy grades of oil, with a total capacity of 6,250,000 gallons, and they are insulated and fitted with steam heating equipment. Oil is discharged from ship through three 8in " Emco " marine unloading arms which are manifolded into 12in and 10in docklines. Six 600 gallons per minute positive displacement pumps distribute the fuel oil to the railcar loading rack, which accommodates ten 20-ton rail tank cars on each side and is equipped with ten " Emco " spring balance master arms.

The conjoint light oil depot, of 1,500,000 gallons capacity, has eleven vertical tanks, each 30ft high, and seven horizontal tanks, each 30ft long, for the storage of motor spirit, kerosene and gas oil. Coastal tankers supply the depot and cargoes are discharged through two 6in " Emco " arms. For handling the light oils there are four 500 gallons per minute and six 250 gallons per minute pumps powered by flameproof electric motors.



Erection of tubular steel roof. The spine girders span 90ft and are 40ft apart. The trussed rafters are propped at their mid-points against the bottom chord of the spine girder

The Aswan Dam Hydro-Electric Scheme

WITH the completion of our pictorial review of 1960 on the accompanying art plates, we also draw attention to one other example of a large overseas project with which British engineers were concerned. On January 10, 1960, President Nasser of the United Arab Republic opened the £30,000,000 Aswan dam hydro-electric scheme, which had been under construction for seven years. The scheme was designed by British consultants with Swedish co-consultants on the civil engineering side, the firms involved being Messrs. Kennedy and Donkin and Messrs. Vattenbyggnadsbyran. For his services for the project, Mr. Geoffrey Kennedy, of Kennedy and Donkin, was awarded the Order of Merit, First Class, by President Nasser at the inauguration ceremony.

International bids were invited for the various different parts of the project and as a result thirty-seven different contracts were placed with contractors of seven different nationalities. This scheme (not to be confused with the Russian High Dam project), utilises the head over the existing dam which was built for irrigation. The head available varies from about 31m to 10m according to the time of the year and the quantity of water to be discharged down the river.

The bulk of the power available is thus not firm and is only suitable to supply an industry which could not afford to pay the high price for a firm supply of electricity. There was an immediate outlet for such non-firm power in Egypt which had for many years relied upon vast quantities of imported nitrate fertiliser and an artificial fertiliser factory was built specially to consume it. The factory is situated on the other side of the Nile closer to Aswan. Its peak demand will exceed 200MW and it will produce over 500,000 tons of fertiliser each year.

The firm power available will be used for supplying pumping stations further down the Nile which will raise water to higher levels than was previously possible and thus bring more land under cultivation.

The power scheme comprises an intake dam and power station built into a depression to the south-west of the existing dam at Aswan. Downstream of the power station there is a surge basin and from this the water is discharged back into the Nile below the existing dam by means of four tunnels each having a cross section of 150 square metres.

The majority of the plant came from various European countries (including the United Kingdom) and was delivered to the Mediterranean port of Alexandria. From Alexandria it was shipped up the Nile to Aswan by barge because this route could carry heavier and bulkier pieces more economically than was possible over the single track railway. To unload the barges on arrival at Aswan a 100-ton Goliath crane over one of the locks associated with the existing dam was one of the first things to be constructed. A fleet of transport vehicles had to be provided for carrying plant from this off-loading point to the construction sites.

Because of the low head and large water quantities available at Aswan the 65,000 h.p. Kaplan turbines (there are seven of them) were some of the largest in the world at the time they were ordered. A typical rotor is shown in the illustration. The generators too were of large dimensions, the rotors having a diameter of 25ft and weighing 450 tons. To lift these rotors after they had been assembled on the loading bay the two 265-ton cranes were coupled in parallel by means of a special 500-ton lifting beam.

The generators are coupled solidly to 11/132kV transformers which are situated on the deck downstream of the power-house immediately above the surge basin. Switching is in an outdoor substation at 132kV whence feeders radiate to the fertiliser factory, to the Nile pumping stations and also to the High Dam project to supply power for the colony and for construction purposes there. Supplies are taken from the 11kV busbars at Aswan for the power plant colony and for Aswan town.

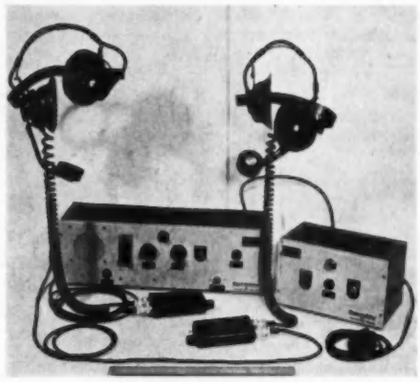
Although some of the contractors were changed at the time of Suez, the engineering and construction proceeded without interruption and the power station was completed to programme in the early part of this year.

Interior of the Aswan dam power station, showing one of the runners of the Kaplan turbines. There are seven 47MW generating sets installed, plus two 11·5MW sets

Intercommunication for Pressurised Suits

EQUIPMENT for intercommunication between persons working in pressurised suits is being introduced by Spembly, Ltd., New Road Avenue, Chatham. The system, suitable for use with the company's own range of pressurised suits, was designed primarily to meet the requirements of the United Kingdom Atomic Energy Authority. It is transistorised, and background air noise is reduced both by a filter to muffle the air supply and a noise limiter in the personal receivers.

A typical fixed installation consists of a control console, or master unit, capable of supplying up to ten slave units allocated to wearers of pressurised suits. A common transistor-regulated power supply feeds all equipments over leads in the speech cables. Provision may be made for switching to a 12V battery supply in case of mains failure. All persons connected to the system are in continuous and direct communication without switching. We illustrate the master unit, power supply unit, and two slave units comprising headsets with boom microphones and the pocket-size personal receivers, which have a durable plastic coating. Connection wires pass through the air hoses of the pressurised suits. The controller can speak to any slave unit through the master unit, but has freedom to move about since he can also use a standard headset and cable plugged into the unit.



Master unit, power unit and personal receivers of pressurised suit intercommunication equipment

The headsets are of the Government approved boom microphone pattern and are fully weatherproofed. Large rubber earpads attenuate, to a large degree, any noise not coming through the amplifier circuit. The boom microphone can also be incorporated in the helmet of the pressurised suit, and alternative forms of headset can be supplied as required.

An overload relay is incorporated in the system which, on operation, prevents further working until the control console has been switched off, the fault removed, and the instrument switched on again.

Similar headsets and personal receivers may also be interconnected through a combined battery power unit and junction box, enabling a portable installation to be set up in a few minutes. Further equipment may be interconnected in this way by the addition of an extension junction box.

[Reply Card No. E572]

Electrode Holder

AN electrode holder for heavy-duty welding which is made by Interlas, Ltd., 9, Church Street, Ampthill, Bedford, has a handle designed to remain cool under extreme working conditions, even when using up to $\frac{5}{16}$in electrodes at up to 600A. This holder, to be seen in the illustration, has the welding cable connected directly to the head instead of running through the handle in the usual way.

Heavy-duty electrode holder

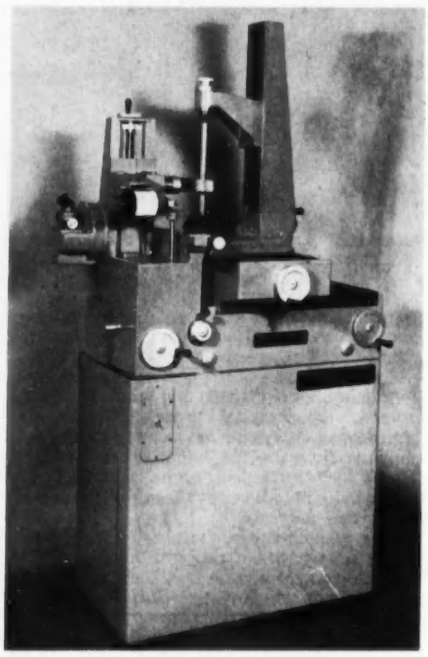
The plastic handle is further protected from heat radiated from the cable by an aluminium-painted metal shield, in a casing under which the cable is housed in an asbestos sheath.

[Reply Card No. E573]

SHORTER REPORTS *(continued)*

Gear Measuring Machine

A COMBINED involute and helix measuring machine recently added to the gear measuring equipment manufactured by the David Brown Tool Division, Park Works, Huddersfield, is designed to take spur and helical gears with base circle diameters from ¾in to 18in. With the centre locating column in position as shown in the illustration below, gears up to 12in diameter



Involute and helix gear measuring machine equipped with mechanical graphic recorder

with 18in between centres are taken, whilst when the centre column is removed gears up to 18in base circle diameter can be accepted. The standard machine is equipped with the maker's mechanical recorder which has a magnification ratio of 500 to 1 and enables the ratio of graph length to slide movement to be varied between 1 to 1 and 3 to 1. A special model of the machine is fitted with a "Talymin" side-acting gauge head with electronic rectilinear recorder and amplifier giving magnification ratios from 100× to 5000×. A gearbox in this recorder allows the ratio, chart length to length of appropriate slide movement to be 1 to 1, 2 to 1, or 4 to 1. It is claimed that on both machines variations in the order of 0·0001in can be accurately recorded.

The individual base disc principle of involute measuring with a different base circle disc for each size of gear is used on the machine. For involute testing the gauging point of the recorder stylus is located precisely above the working face of the straight-edge and the base disc, mounted co-axially with the gear under test, is brought into contact with the straight-edge. Rolling of the base disc along the straight-edge by movement of the slide mounting causes the gauging point in contact with the appropriate gear tooth flank to describe the designed involute curve. If the flank is a true involute a straight line graph will be recorded, whilst any deviation from the true involute will be recorded by movement of the pen across the graph paper. By the same means, modified tooth forms may be recorded for comparison with the designed profile, and scales are provided on the machine so that positions where departures from the involute form occur can be accurately located.

When helix testing, vertical movement of the stylus is combined with a corresponding vertical movement of the gear, and the gauging point describes the correct helix. The vertical slide carrying the recorder also houses the helix disc, rotation of which allows the centre line of a slot machined in its face to be inclined at the base helix angle of the gear. The straight-edge, mounted on a sensitive slide, is coupled to the helix by a block which is free to slide in the helix disc slot. An illuminated direct reading microscope is provided for setting the base helix angle. The base disc is brought into contact with the straight-edge and the gauging point of the stylus into contact with the tooth flank at one end of the gear face. The movement of the vertical slide causes the stylus to traverse axially across the gear face whilst the helix disc moves the straight-edge and causes the gear, mounted co-axially with the base disc, to rotate by the correct amount. Any deviation from the correct helix, measured in the transverse plane of the gear, is thus recorded.

In combining the dual functions of involute and helix testing these measuring machines are designed to meet the requirements of gearing manufacturers, and the machines are built to meet all the normal requirements of standards room, inspection and shop use for the measuring of gear helices and involutes.

[Reply Card No. E581]

C.E.G.B. Generating Plant Installed in 1960

NEW electrical generating plant with a total output capacity of 1935MW was installed by the Central Electricity Generating Board in the year ended December 31, 1960. The corresponding total for the previous year was 1670MW, as recorded in THE ENGINEER, January 15, 1960.

The new plant installed in 1960 is listed in the accompanying table, from which it will be seen that twenty-one turbo-generators (with a total installed capacity of 2060MW) and twenty-two boilers (with a total evaporative capacity of 15,890,000 lb of steam per hour) were installed in fourteen power stations. Four of these stations are new ones; another is a new section of a station; and the remainder are existing stations to which extensions have been made.

A point of interest is the growing preponderance of larger sets (120MW and 200MW capacity) compared with the 60MW sets hitherto regarded as "standard." The six 60MW sets installed in 1960 represented only 17·5 per cent of the total new plant capacity, whereas the ten 60MW sets installed in 1959 accounted for 33 per cent of that year's new plant capacity. On the other hand nine 120MW sets were commissioned in 1960 compared with five in 1959.

Three 200MW generating sets (the largest yet installed by the Board) are in service at High Marnham power station on the River Trent. The steam conditions there are 2300 lb per square inch at 1050 deg. Fah., with reheat to 1000 deg. Fah. after partial expansion.

The "Dot" Diode

EQUIPMENT has been provided at the laboratories of Hughes International (U.K.), Ltd., Glenrothes, Fife, Scotland, to produce a new microminiature diode developed by the Hughes Semiconductor Division in the U.S.A. This is a silicon subminiature unit called a "dot" diode measuring 0·05in diameter by 0·03in thick, these dimensions having been adopted for a range of active elements such as diodes and transistors for assembly into circuits evaporated, chemically etched or deposited, or otherwise formed on the two major faces of a board. The substrate is 0·03in deep and the devices are carried in 0·052in diameter through holes. In the case of the diode it is suggested that connection between the end-plates and the circuitry should be made by means of conductive pastes.

The metal end-plates of the diode are gold clad, and the anode is distinguished from the gold-colour cathode by silver-colour plating over the gold cladding. To facilitate assembly, the cathode end-plate is magnetic so that the diode can be picked up and inserted in the circuit by a suitable tool (modified from a ball-point pen). The anode end-plate is non-magnetic. Automatic assembly could therefore be arranged without risk of the diode being inserted with the wrong polarity. Specification limits of this experimental diode are: 100mA forward current at 1V; 0·1μA reverse at 50V d.c.; 100V breakdown at 10μA; operating temperature range −55 deg. to +100 deg. Cent.

The diode is a step in the first stage of microminiaturisation development on which the Hughes Semiconductor Division is engaged. In this stage diodes, transistors, resistors and capacitors all take the form described above and would be assembled in holes on an 0·1in square matrix. As an example, a full adder containing eighty-five resistors, capacitors, diodes and transistors could be contained upon and within a board approximately 0·04in by 2in by 2¾in.

[Reply Card No. E583]

C.E.G.B. Electrical Generating Plant Commissioned in 1960

Power station	Project group	Turbo-generator plant		Boiler plant		Main high-pressure pipework
		Installed capacity, MW	Maker	Capacity, klb per hour	Maker	Maker
*Aberthaw	Midlands	2×100	C. A. Parsons	2×755	Foster Wheeler	Stewarts and Lloyds
Agecroft "C"	Northern	1×200	A.E.I.	1×860	International Combusion	Stewarts and Lloyds
Belvedere L.P.	Southern	1×60	English Electric	1×550	John Brown	Aiton
Blyth "A"	Northern	1×120	A.E.I.	1×860	Babcock and Wilcox	Babcock and Wilcox
Bold "B"	Northern	1×60	G.E.C.	1×550	John Thompson	John Thompson
Drakelow "B"	Midlands	2×120	C. A. Parsons	2×860	Foster Wheeler	John Thompson
Elland	Northern	1×60	A.E.I.	1×550	John Brown	John Thompson
High Marnham	Midlands/Northern	2×200	English Electric	2×1,400	International Combustion	Aiton
*Northfleet	Southern	3×120	G.E.C.	3×860	Foster Wheeler	Babcock and Wilcox
†Plymouth "B" H.P.	Southern	2×60	A.E.I.	2×550	Babcock and Wilcox	John Thompson
*Skelton Grange "B"	Northern	1×120	C. A. Parsons	1×860	Mitchell Engineering	Aiton
South Denes	Southern	1×60	Richardsons Westgarth	1×550	Mitchell Engineering	John Thompson
Spondon "H"	Midlands	2×10	A.E.I.	3×180	Foster Wheeler	Aiton
*Staythorpe "B"	Midlands	1×120	A.E.I.	1×860	John Brown	Babcock and Wilcox

In addition to the above, the following boilers have been completed but not commissioned as associated turbo-generators are not yet available: Belvedere H.P. Boiler No. 5, 860 klb per hour capacity, manufactured by John Brown; Rugeley, Boiler No. 1, 860 klb per hour capacity, manufactured by Babcock and Wilcox.

* New stations in which plant has been first commissioned in 1960.

† New sections. The remainder are existing stations to which extensions have been made.

INDUSTRIAL NEWS

Shipbuilding Wages

On Monday of this week the Shipbuilding Employers' Federation announced that it had decided to increase shipyard wages by 8s. 6d. a week for skilled workers, 8s. for semi-skilled workers and 7s. 6d. for unskilled workers, with effect from normal starting time, Monday, January 9. The increases were given on the agreement that the Confederation of Shipbuilding and Engineering Unions meet the Federation in committee at an early date and discuss steps to be taken to improve the competitive position of the industry.

Mr. John Rannie, president of the Shipbuilding Employers' Federation, pointed out, before the parties went into committee on Monday to discuss the terms of an agreement, that the Federation had consulted its district associations, every one of which had reported with emphasis that in shipbuilding and ship repairing costs must be reduced from present levels to enable the industry to get further orders. Many districts had stated that they simply could not afford any increase in wages. It was expected, Mr. Rannie went on to say, that the total order book at December 31 would be lower than it had been for at least ten years. The recent wages settlement in the engineering industry had caused dismay to the Federation's members, Mr. Rannie added, as it would certainly result in an increase in the cost of many of the components which go into a ship. In a period of fixed prices, he continued, this was a serious matter for shipbuilders and ship repairers alike, and might force shipbuilders to purchase components abroad, a proccdure which the industry wished to avoid if at all possible.

Unemployment

The Ministry of Labour reports that on December 12, 1960, there were 365,051 people registered as unemployed in Great Britain, of whom 322,807 were wholly unemployed and 42,244 temporarily stopped. The total of 365,051 includes 46,513 married women and 1466 school leavers. The number of people unemployed for more than eight weeks was 166,226, which was 51 per cent of the wholly unemployed.

The main changes in unemployment between November 14 and December 12, the Ministry points out, were increases of 17,600 in motor vehicle manufacture, including 16,500 temporarily stopped ; and 1500 in construction. Unemployment in shipbuilding and marine engineering was reduced by 3700.

During the period November 10 to December 7, the Ministry says, there were decreases in the number of unfilled vacancies in almost all industries. Unfilled vacancies in the manufacturing industries as a whole fell by 6100.

Employment

During November, 1960, the Ministry of Labour states, the number of people in civil employment in Great Britain is estimated to have increased by 17,000 to 23,839,000. Among the more significant increases were the distributive trades, in which the number of people employed rose by 55,000 to 3,362,000, and in the engineering and electrical goods group in which there was an increase of 6000 during the month, bringing the total number of people employed to 2,107,000. The main reductions, the Ministry says, were of 25,000 in agriculture, 10,000 in construction, 9000 in catering, hotels, &c., and 8000 in motor vehicle manufacture.

According to the latest statistics issued by the Ministry of Labour, the number of operatives working overtime in manufacturing industries in the week ended November 26, 1960, was 1,783,000, which was 70,000 more than at the end of August. In the same week the number of operatives working short time in manufacturing industries was 126,000, which was 31,000 more than at the end of October and 95,000 more than at the end of August. The total included 81,000 in the motor vehicle industry. The average number of hours of overtime worked by each operative on overtime was eight, the Ministry says, whilst the average number of hours lost by each operative on short time was eight and a half.

Objective for 1961

An article in the current issue of the British Employers' Confederation's *Bulletin* suggests that twin problems for employers in 1961 will be how to avoid inflation and how to remain competitive in labour costs. To some extent, the *Bulletin* adds, the problems boil down to the prior question of how to make the best use of the existing manpower in a country where, provided it avoids major disputes, most grades of manpower and all grades of skilled manpower are likely to remain indefinitely in short supply. Unemployment in Great Britain at the close of 1960 stood at 1·6 per cent or 365,063 persons registered as unemployed, with 293,905 vacancies unfilled.

In many workshops and factories life will tend to go on in 1961 much as it did in 1960 or 1959, the Confederation says, with the same men doing much the same jobs in much the same way. In a changing world there is still a reluctance to change. Many employers, the *Bulletin* adds, much prefer to keep their work force intact on short time rather than disband teams which work well together and to face the difficulties of recruiting when recruiting becomes difficult. Many trade union leaders have expressed their readiness to help in increasing productivity since they recognise that in the long run this will pay their members best, and yet there are many, the Corporation points out, who still cherish the view that increased productivity means fewer jobs and harder work for those who remain, and therefore is a bad thing for the working man.

Great Britain can no longer afford to employ three men on a job which can safely and reasonably be done by two. Conversely, if three men are needed she cannot afford restrictions in the intake of men to a particular craft so that only two are available. The employment of every man so that he can make the best contribution of which he is capable is most likely to bring satisfaction to him, the *Bulletin* says : it would bring prosperity to the nation. The difficulties are enormous but the prizes are equally great and well worth putting forward as a main objective for 1961.

Technical Education

A major reconstruction of the system of courses for technicians, craftsmen and operatives in technical colleges is proposed in the White Paper " Better Opportunities in Technical Education " which was published last week. The changes proposed have four main objects. They are intended to broaden the education received by students and to provide the maximum continuity between education at school and technical college. Secondly, they will adapt the system more closely to the needs of industry, and in particular meet the urgent need to make more and better provision for technicians. Thirdly, they will increase the variety of courses available to students according to their aptitudes and the careers they wish to follow. Fourthly, the White Paper states, they should substantially reduce the wastage which occurs at present owing to the failure of so many students to complete their courses successfully.

The chief proposals are as follows. Students should start at a technical college immediately after leaving school. Preliminary courses in evening institutes should be discontinued. More care should be taken in the selection of students for courses. Colleges should experiment with full-time induction courses and with tutorial methods. The courses will include National Certificate and Diploma courses for students aiming to become at least high grade technicians ; technician courses devised specifically for particular industries ; craft courses ; and courses for operatives. Ordinary National Certificate courses will last two instead of three years and the standards of entry will be raised. There will be new courses of four to five years specially for technicians. New general courses will be introduced, leading to either technician courses or Ordinary National Certificate and Diploma courses. Craft courses will be modified. Courses for operatives should be vigorously developed. More time should be provided under day release schemes. No student should have to rely wholly on evening study. Sandwich courses, especially for technicians, and block release courses should be increasingly developed.

The White Paper can only suggest a general pattern within which the many bodies responsible for the actual planning and provision of courses should do their work, and it will be for the bodies concerned to announce the new arrangements in particular cases as soon as they are settled. Many hundreds of existing courses will have to be reviewed and many new ones planned from the start. The most urgent and difficult task, the White Paper points out, will be the preparation of the proposed new courses for technicians, including the new general courses, in the industries where they are needed. The White Paper goes on to say that the system of technical education will only be able to make its full contribution if it is geared to the rapidly changing requirements of modern industry.

Commenting on the proposals at a press conference held last week, Sir David Eccles, Minister of Education, said that in future the intention was that the last years at school and the first years in work should be, and should be seen to be, a continuous period of education.

PERSONAL AND BUSINESS

Appointments

Mr. H. V. Didlock has been appointed a director of J. and P. Supplies, Ltd.

Mr. G. E. Jowitt, company secretary, has been appointed to the board of directors of Lang Pneumatic, Ltd.

The Ministry of Aviation announces that Mr. P. Lloyd has been appointed director general of engine research and development.

Precision Machinery Services, Ltd., a subsidiary of Modern Machine Tools, Ltd., has appointed Mr. E. Smith as works manager.

Mr. R. H. Thornicroft has been appointed manager, traffic department, A.E.I. (Rugby), Ltd., in succession to Mr. G. O. Pritchard.

Mr. H. J. Billing, A.M.I.Mech.E., sales director of Metalastik, Ltd., has been appointed to the board of the John Bull Rubber Company, Ltd.

Thos. Firth and John Brown, Ltd., announces that Mr. A. Broomhead has been appointed deputy managing director. Mr. F. Wortley, a director, has been appointed general works manager.

The Admiralty announces that Mr. J. H. B. Chapman will retire as Director of Naval Construction in April and will be succeeded by Mr. A. N. Harrison, the present Assistant Director of Naval Construction.

Samuel Fox and Co., Ltd., a subsidiary of The United Steel Companies, Ltd., announces that Mr. R. D. Pollard has been appointed director of metallurgy, and Mr. R. Wilcock has been appointed chief metallurgist.

The A.P.V. Company, Ltd., announces that Mr. P. W. Seligman has been appointed deputy chairman, while retaining his position of managing director, and Mr. H. P. N. Benson has also been appointed managing director.

Mr. Norman Daniel, assistant general manager of Semtex, Ltd., is to take over the post of general purchasing manager for the Dunlop Group. He succeeds Mr. D. J. Flunder, who is taking up a senior position in the tyre division.

The Ministry of Aviation has announced that the appointment of Mr. C. F. Uwins as chairman and managing director of Short Brothers and Harland, Ltd., has been extended from January 1, 1961, pending a permanent appointment.

Midland Heating and Ventilation Company, Ltd., announces that Mr. J. B. Mattei, A.M.I.Mech.E., has been appointed to its London sales organisation. He will also be responsible for the sales of its associate company, Carter Thermal Engineering, Ltd.

Mr. A. H. Wilson, M.I.E.E., M.I.Mar.E., senior engineer and ship surveyor in the consultative branch of the Ministry of Transport, has been appointed chief examiner of engines in succession to Mr. S. Hogg, M.I.Mech.E., M.I.Mar.E., M.I.N.A.

QVF, Ltd., states that it has added six new sales representatives to its sales force. They are Mr. D. McNab, north-east England ; Mr. R. Lee, south-east England ; Mr. S. W. Richardson, eastern England ; Mr. K. Heath, west of England and North Wales ; Mr. R. Jenkins, Scotland ; and Mr. J. Peace, south-west England.

Mr. C. G. James, A.F.R.Ae.S., has been appointed managing director of Fairey Marine Ltd. He succeeds Mr. C. H. Chichester Smith, A.F.R.Ae.S., formerly chairman and managing director. Mr. Chichester Smith retains the chairmanship. Mr. Charles Currey, A.M.R.I.N.A., and Mr. A. R. Sibley have been appointed to the board of directors.

Mr. J. Arthur Reavell, M.I.Mech.E., chairman of the Kestner Evaporator and Engineering Company, Ltd., and the Kestner Group of companies, retired from the chair on December 31, 1960, after fifty-three years with the company, and assumed an appointment as the company's first president. The chairmanship of the company has been undertaken by his son, Mr. Brian N. Reavell, M.I.Mech.E.

Mr. David Morgan Rees, former chairman of the south-western division of the National Coal Board, has been appointed chairman of Rhymney Engineering Company, Ltd. Mr. John Morgan Mayer, A.M.I.Mech.E., joint managing director of International Combustion (Holdings), Ltd., has been appointed deputy chairman. The Rt. Hon. The Viscount Hall and Mr. Alfred Read have retired from the board. Mr. W. M. Regan has been appointed secretary of the company.

Wadkin, Ltd., states that Mr. C. H. Morris has retired from the managing directorship but retains his seat on the board as vice-chairman. Mr. S. Radcliffe, A.M.I.Mech.E., joint assistant managing director, becomes joint managing director (engineering) ; Mr. W. L. Sims, M.I.E.E., M.I.Mech.E., joint assistant managing director, becomes joint managing director (commercial). Mr. Walter Howe, A.M.I.E.E., chief electrical engineer, and Mr. Philip Morris, research and design, have been appointed to the board.

Business Announcements

Ruston-Bucyrus, Ltd., has opened a sales and service depot at 2430, London Road, Carmyle, Glasgow (telephone, Shettleston 4264/5).

The Institute of Road Transport Engineers states that its address is now 1, Cromwell Place, Kensington, London, S.W.7 (telephone, Kensington 3744).

Engineering and Allied Employers' National Federation, Broadway House, Tothill Street, Westminster, London, S.W.1, has changed its name to Engineering Employers' Federation.

Mortimer Machine Tool Company, Ltd., Mortimer House, Acton Lane, London, N.W.10, has been appointed sole and exclusive agent for the Buhr Machine Tool Company, Ann Arbor, Michigan, U.S.A.

The British Aluminium Company, Ltd., Norfolk House, St. James's Square, London, S.W.1, states that its head office telephone exchange has been enlarged to sixty lines. The new number is Trafalgar 8888.

Lawrence Edwards and co. (Engineers), Ltd., Commercial Buildings, Oxford Street, Kidderminster, has moved to Stourport Road, Kidderminster. The telephone number, Kidderminster 3665/6, remains unchanged.

The Agricultural Engineers' Association states that Mr. Walter Drew resigned from all his offices in the Association on December 31, 1960, for personal reasons. He has accepted the post of secretary to the Royal Lancashire Agricultural Society.

Elgar Machine Tool Company, Ltd., 172-178, Victoria Road, Acton, London, W.3, has been appointed the exclusive distributor in the United Kingdom for the range of vacuum forming and horizontal cutting machines manufactured by Messrs. Illig.

Aabacas Engineering Company, Ltd., Birkenhead, state that its telephone number has been changed to Birkenhead 6673. The company's Birmingham representative is B. Clarke and Sons, Ltd., 1292, Bristol Road South, Longbridge, Birmingham, 31 (telephone, Priory 3437).

Keelavite Hydraulics, Ltd., Allesley, Coventry, has acquired marketing rights for the "Hydro-Titan" hydraulic axial piston units in the United Kingdom and the Commonwealth. The company has also acquired world selling rights for the "Keelavite/Gury" range of high-pressure hydraulic equipment.

Thomas Tilling, Ltd., has announced the purchase of the entire ordinary share capital of the Universal Pattern and Precision Engineering Company, Ltd., of Crawley, Sussex. Lime-Sand Mortar, Ltd., Knaresborough, Yorkshire, a subsidiary of Thomas Tilling, Ltd., has acquired Gibsons of Newcastle, ready mixed concrete manufacturers, plant hire contractors, and sand and gravel producers.

Mullard, Ltd., Mullard House, Torrington Place, London, W.C.1, announces that its component division has now been sub-divided, under its divisional head, Mr. A. F. T. Marner, into four commercial product groups. These groups are : Permanent Magnets, manager, Mr. B. C. Foreman ; Ferrites, manager, Mr. W. A. Everden; Computers, manager, Mr. K. R. Patrick ; Radio and Television, manager, Mr. W. K. Bailiff.

The Manganese Bronze and Brass Company, Ltd., 2, London Wall Buildings, London, E.C.2, announces that its subsidiaries, Dean and Son (Yorkshire), Ltd., and Lightalloys, Ltd., have gone into voluntary liquidation and have now become the Deans and Lightalloys division of the Manganese Bronze and Brass Company, Ltd. A central sales office has been established at 10-12, Cork Street, London. All production facilities for the new division will be housed in a large modern foundry in Beverley, Yorkshire. The Lightalloy factory at Willesden will be closed down.

Contracts

Sir Lindsay Parkinson and Co., Ltd., has received a contract amounting to approximately £2,200,000 from the Central Electricity Generating Board for the river works of the circulating water system for the nuclear power station at Oldbury, Gloucestershire. The contract includes the construction of a reservoir on the river foreshore and site preparation.

Powell Duffryn-Coppee, Ltd., has been awarded a contract valued at over £500,000 for a battery of twenty-five coke ovens and ancillary plant for the Rhodesian Iron and Steel Company, Redcliff, Southern Rhodesia. This battery constitutes an extension to the contract recently completed by Powell Duffryn-Coppee, Ltd., for the supply of a complete coal preparation plant, coke ovens and associated by-products plant at Risco's steel works. The original twenty-five coke ovens were designed to produce 125,000 short tons of coke a year and the new battery when completed will double this output.

G.W.B. Furnaces, Ltd., P.O. Box No. 4, Dibdale Works, Dudley, Worcestershire, has obtained an order for four electric arc furnaces for the Steel Peech and Tozer Works, Rotherham, of the United Steel Companies, Ltd. This is an extension of the contract obtained by G.W.B. Furnaces for two furnaces of the same type for the same customer. The furnaces, which are to the basic mechanical design of Demag-Elektrometallurgie, are each of 150 tons nominal capacity, and will have individual electrical ratings of 40,000kVA. The steelwork for the furnaces will be fabricated by the Distington Engineering Company, Ltd., a subsidiary of United Steel.

Associated Electrical Industries, Ltd., has obtained orders from the Electricity Commission of New South Wales, Australia, for a 275MW turbo-generator (the largest in the southern hemisphere) worth about £2,000,000, and thirteen transformers worth about £1,000,000. The turbo-generator will be made in Manchester and installed at Vales Point power station, 70 miles north of Sydney. It will incorporate a four-cylinder, 3000 r.p.m. turbine with stop-valve steam conditions of 2300 lb per square inch gauge at 1050 deg. Fah., exhausting at 2in Hg absolute with cooling water at 75 deg. Fah., and will have seven-stage feed heating to a final temperature of 485 deg. Fah. The alternator, direct-coupled to the turbine, will be rated at 305,555kVA, 0·9 p.f. at 50 c/s, 16·5kV, three-phase, with water-cooled stator windings and hydrogen-cooled (30 lb per square inch gauge) rotor. To simplify transport and erection caged core construction will be used and the outer casing will be in three sections. Seven of the transformers are for Sydney North ; they are auto-transformers, rated at 133MVA single-phase, and will be star-connected to form two 400MVA banks with one spare unit, the voltage ratio being 330/138·6/15·5kV. High-speed resistance-transfer on-load tap-changers will give voltage variations of ±10 per cent in twenty steps. Natural cooling is used up to 60 per cent rating and above that is augmented by oil pumps and air fans. The other seven transformers are 60MVA, three-phase units for Bunnerong power station ; they are double-wound star/star-delta connected, with a voltage ratio of 132/33/11kV, the high-voltage being variable between ±20 per cent in sixteen steps. The transformers will be made at Rugby.

Award

The Society of Chemical Industry announces that its medal for 1961 has been awarded to Sir Cyril Hinshelwood. The medal is presented every two years for conspicuous services to applied chemistry by research, discovery, invention or improvements.

Miscellanea

Diffused Junction Power Transistors.—Three silicon power transistors have been introduced by the Semiconductor Department of A.E.I. Radio and Electronic Components Division, 155, Charing Cross Road, London, W.C.2. These Ediswan Mazda n-p-n diffused junction devices, types XC703, XC713, and XC723 are intended for a wide variety of industrial applications in equipment operating at temperatures ranging from −65 deg. Cent. to +175 deg. Cent. They are recommended for power-switching circuits, oscillator regulator and pulse amplifier circuits, and as class "A" and class "B" push-pull audio and servo amplifiers. At 100 deg. Cent. they offer a range of dissipation from 2W to 30W.

THE AMERICAN SCENE

By Our American Editor

Gauge Block Developments at the National Bureau of Standards

No. II—(*Continued from page 31, January 6, 1961*)

Increased demands on modern technology have established a requirement for gauge blocks with higher accuracy of length calibration than is currently available. The desired improvement is tenfold and involves an increase in reliability from 2×10^{-6}*in per inch to* 1 *or* 2×10^{-7}*in per inch. The problem of achieving gauge blocks dimensionally stable to this degree is fundamental and has two aspects :* (1) *the development of a suitable material and treatment to produce a gauge block with the desired dimensional stability, surface quality, and several other physical properties ;* (2) *the development of instrumentation and techniques for the precise measurement of temporal changes of length, so that stability of test samples may be determined to the required precision. To date the programme has been successful in developing three sets of gauge blocks from two materials that have met the requirements and have shown a dimensional stability of* 2×10^{-7}*in per inch per year over an observed period of one year.*

Processing and Fabrication

EACH type of steel was obtained from a single heat and was commercially made in accordance with the accepted practices for that type, so that it would represent typical steels available on the market. With the exception of the T15 and 17–4 PH steels, each was hot rolled by the manufacturer into rectangular bars 1¼in by ½in. After hot rolling and straightening, all bars were fully annealed by the manufacturer and precautionary measures taken to hold decarburisation to a minimum. The gauge blocks made from these bars were rectangular parallelepipeds with a gauging length of 2in and other dimensions of 1¼in. add ¼in.

With hardened steels, the difficulty of completely balancing the dimensional changes occurring from structural transformations against residual stresses can be minimised by keeping these factors at low levels. As a starting point, it was decided to eliminate almost all of the retained austenite, which would reduce the possibility of growth and provide data on the stability characteristics of an austenite-free steel, and would possibly give a higher hardness and allow a higher tempering temperature or longer time at temperature to obtain a final hardness of 65 Rockwell C. The higher tempering temperature was considered beneficial in the reduction of residual stresses. The standard procedure used for hardening by direct quench was to austenitise at 1550 deg. Fah. for fifteen minutes and quench to room temperature in a quenching oil having an accelerated cooling rate. The residual stresses resulting from thermal gradients on cooling from the hardening temperature are often reduced by martempering. The martempering treatment adopted consisted of austenitising in a chloride bath at 1550 deg. Fah. for fifteen minutes, quenching in a sodium nitrate-nitrite bath at 300 deg. Fah. for thirty seconds, and then quenching to room temperature in oil.

Both of these hardening treatments were followed by a stabilisation treatment designed to remove retained austenite, temper the martensite, and reduce residual stresses. This treatment for blocks hardened to 65 Rockwell C consisted of an immediate refrigeration at −140 deg. Fah. for an overnight period of eighteen hours to twenty-two hours, followed by a tempering treatment at 250 deg. Fah. for one hour, a second refrigeration treatment at −140 deg. Fah. for an overnight period, and a final temper at 250 deg. Fah. for nine hours. The interval between steps was kept as short as possible. The temperature of the final temper was raised in some instances where a hardness of less than 65 Rockwell C was desired. The prescribed hardness of 65 Rockwell C is believed to have been an arbitrary selection to obtain good wear resistance, and it was thought that a block with slightly lower hardness, such as 62 or 60 Rockwell C, might be satisfactory from a wear standpoint and possess greater stability. A stress relieving treatment was applied to all gauge blocks after finish machining and prior to final lapping.

The 410 stainless was the first of the group 2 materials studied. The 410 steel was to be used in the annealed condition only, with the surface nitrided or otherwise hardened. Tests were run to establish suitable procedures for nitriding this steel. No unusual techniques were required for effective nitriding. The surfaces of the blocks were prepared by grinding and thereafter were scrubbed in an aqueous detergent just prior to nitriding (Fig. 4). A nitriding time of forty hours to forty-four hours at 1010 deg. to 1030 deg. Fah. produced a case about 0·009in thick. The dissociation of the ammonia was maintained at 20 to 25 per cent. As the result of nitriding, the blocks grew different amounts in each of the three directions ; about 0·0025in in the 2in dimension, 0·0020in in the 1¼in dimension, and 0·0015in in the ¼in dimension.

The two-stage Floe process was also employed in an attempt to reduce or eliminate the white layer formed with conventional single-stage nitriding. In this process, the first step consisted of nitriding for twenty hours to twenty-four hours at 1000 deg. Fah. with a dissociation of 20 to 25 per cent. Thereafter, the temperature of the retort was raised to 1050 deg. Fah. and cracked ammonia blended with the uncracked ammonia to give a dissociation of 75 to 80 per cent. The second stage was maintained for about twenty-four hours. The hardness of the case nitrided by the single-stage process exceeded 1260 KHN (Knoop Hardness Number, 200 gramme load) over its entirety. The hardness of the case produced with the two-stage process was somewhat less than the case formed with single-stage nitriding. Immediately adjacent to the surface the hardness was 880 KHN, the greater portion of the case had a hardness of 1020 KHN, and next to the core, hardness fell to 1020 KHN (500 gramme loads). All of these values are appreciably greater than the minimum of 65 Rockwell C specified for gauging surfaces.

In the grinding and lapping operations applied to the gauging surfaces after nitriding, approximately 0·0025in was removed, which left from 0·006in to 0·007in of the case. The finish produced on the nitrided 410 blocks by commercial lapping is worthy of note. It was superior to finishes produced on hardened 52100 steel, but took about one-third more time for the removal of equivalent amounts of stock. The final microfinish, as measured with a tracer surface roughness instrument, closely approached zero, and the wringing characteristics were excellent.

The corrosion resistance of the case is different from that of the original steel. Dilute nitric acid and Vilella's reagent attack the nitrided layers more readily than the ferritic matrix. On the other hand, the nitrided surfaces are less subject to coating by tinted surface films in such processes as stress relieving in a cracked ammonia atmosphere. Nitrided and lapped surfaces with no protective wrapping, oil or wax film, or other corrosion preventive treatments have been exposed for two years under normal indoor conditions of humidity and temperature in the atmosphere of Washington, D.C., and have

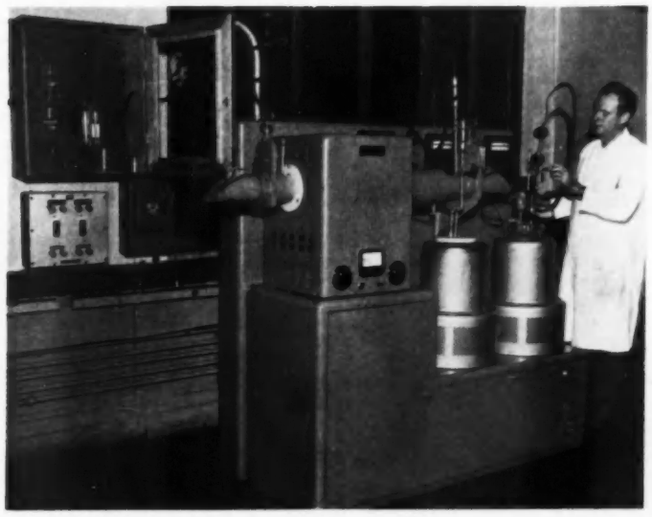


Fig. 4—Nitriding of type 410 stainless steel gauge blocks by exposing them to a dissociated ammonia atmosphere

THE AMERICAN SCENE *(continued)*

shown no tendency to become dull or to rust.

The single-stage nitriding treatment was applied to two series of blocks that were fabricated differently after nitriding. In one series the nitrided layer was completely removed from the four non-gauging faces by grinding parallel to the 2in dimension. In the other series, only about 0·002in was ground from each non-gauging surface so as to produce a bright nitrided finish. The first series, as a result, was finished with

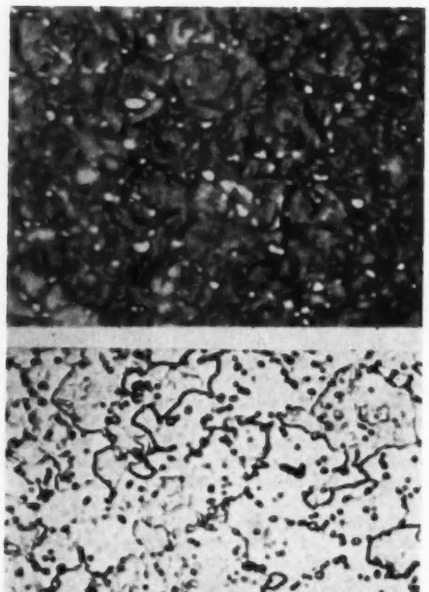


Fig. 5—Photomicrographs of type 410 stainless steel in the nitrided (top) and un-nitrided (bottom) condition

nitrided cases on the two gauging faces only, while the second series had nitrided cases all over. In a third series, the blocks were nitrided by the two-stage process, and the four non-gauging surfaces were not ground or otherwise disturbed after nitriding.

Both the 52100 steel and the 410 stainless steel were coated with hard-facing materials in four different ways : (1) thermal spraying with a nickel-chromium-boron alloy ; (2) flame plating with tungsten carbide ; (3) flame plating with aluminium oxide ; (4) electro-plating with chromium. In each instance the base material was in the annealed condition.

The hardening and stabilisation of the 52100 steel, the nitriding of the 410 stainless steel and the chromium electroplating were carried out in laboratories of the National Bureau of Standards. Thermal spraying of nickel-chromium-boron alloy and flame plating with tungsten carbide were applied by commercial firms. All machining operations except lapping were performed in the Bureau's machine shop. Lapping was done by the Brown and Sharpe Manufacturing Company, the Dearborn Gage Company, the DoAll Company, and the Pratt and Whitney Company, in accordance with the best commercial practices.

Measuring Techniques

The measurement phase of the stability programme required a testing technique that would provide frequent measurements of a large number of test samples and precision of length measurement on the order of two parts in 10,000,000. The degree of precision would determine the time interval required to acquire significant data indicating change of length of the test samples. Frequent measurements would provide information on the nature of the change. As the test samples are 2in in length, a practical limitation to the error of measurement of 0·4μin was established as a goal.

To establish the change in length of the test samples it was necessary to define a length scale whose stability characteristics were known. An ideal procedure would be to compare the sample with a length scale formed by the interference of light of known wavelength. It is generally believed that a wavelength of light, λ, is constant in time and may be expressed by

$$\lambda = \frac{c}{\mu\nu}$$

where c is the velocity of light in vacuum, μ is the index of refraction of the material through which the light is transmitted, ν is the frequency of light radiation. Procedures and instrumentation are available that provide such absolute measurements of the test samples. Although the Bureau is now engaged in the development of procedures and instrumentation to achieve precision in such absolute measurements to one or two parts in 10,000,000, the best that could be done when the stability programme was initiated was one part in 1,000,000. The precision of such measurements is limited by the differing effects of temperature on the sample and the interference scale formed in the air surrounding the sample. The index of refraction of air is dependent upon temperature, so from the above equation it is observed that the wavelength of light is dependent upon temperature. For visible light in an approximate standard atmosphere of 760mm Hg, 68 deg. Fah., the wavelength scale might be considered as having a coefficient of expansion approximately one-tenth that of steel, which was the material used for most of the stability samples. In addition, problems are encountered if the temperature of the measurement area is not stable. Because of thermal lag, the temperature of the air in which the wavelength scale is formed will, in general, be different from the temperature of the sample. Thus the relationship between the sample and the wavelength scale is critically dependent upon temperature, and the effective temperature of the sample can be difficult to determine as the axial temperature of the sample is likely to differ from its surroundings.

One method of avoiding difficulties of this nature is to resort to comparison measurements where the length of the test sample is compared with a standard length having thermal properties similar to those of the sample. A specially designed optical interference comparator of a type originally developed by Kosters was available that could be relied upon to provide precision to approximately one part in 10,000,000. As most of the test samples were steel blocks 1⅛in by ⅜in by 2in long, it was considered highly desirable to select as a standard of length a steel gauge block with the same cross-sectional size and nominal length and having a long history of absolute length measurements to indicate stability. Absolute measurements made at irregular periods since January, 1954, on a 2in steel gauge block serving as a length standard for the N.B.S. Engineering Metrology Section indicated it to be exceedingly stable. The curve best fitting the measurement data indicated that its growth had not exceeded 0·2μin since the measurement series began. This gauge block was chosen as the basic reference length for the stability measurement programme. Since the initiation of the programme this block has been subjected to more frequent absolute length measurements, and these recent measurements continue to justify its choice as a stable standard.

The difficulty encountered in using the interference comparator as the measuring instrument was an insufficient testing capacity to measure all the test samples as frequently as desired. For test samples of 2in length, a minimum time of four hours is considered necessary between the operation of wringing the test specimen to the platen and the comparison of this specimen with the master gauge block. This interval is believed necessary to allow the test specimen to attain thermal equilibrium with the master block and to allow the wringing film to attain its minimum thickness in case more wringing lubricant is used than is necessary. During this time interval, it is necessary to maintain the platen in the location occupied during the measurement. Thus, the need for this time interval limited the test capacity of the interferometer.

During the initial months of investigation of any specimen, it was desired that its length be determined weekly. Thus it was foreseen that a test programme having a capacity of fifty measurements a week was required. The classical methods of precise length comparison rely upon the comparison of static lengths and are time consuming because they require thermal equilibrium. The most apparent solution to the problem of increasing test capacity was to abandon the concept of static length comparisons and replace it with the concept of dynamic length comparisons. In general, such comparisons had not been refined to a degree giving the precision that was required. It was questionable whether the instrumentation usually employed in such comparisons would provide the necessary repeatability.

The accompanying illustration (Fig. 6) indicates schematically a typical mechanical comparator employed in dynamic length comparisons. The

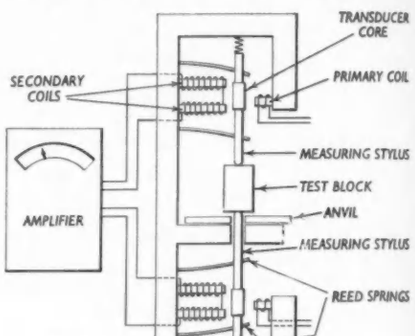


Fig. 6—Diagram of mechanical comparator employing an amplified transducer signal to indicate the length of the gauge block

measuring styluses are mounted in reed spring systems to avoid binding that could be encountered in piston-cylinder arrangements. A core of a moving core transducer is mounted on each stylus. A moving core transducer consists of a primary coil and two oppositely wound secondary coils. The relative potential induced in each secondary is dependent upon the position of the core. Thus, the position of the stylus is indicated. Amplification of the signal is provided so that deflection of the milliammeter needle magnifies movement of the stylus by approximately 2×10^5. In this instrument the top and bottom transducers provide opposing signals of equal magnitude so that the effects of translation of the test piece in the direction of its critical length are cancelled in the combined signal. This reduces the need for extremely critical seating of the test piece on the anvil. Comparison of length is accomplished by noting the difference in readings of the calibrated scale as the test pieces are successively positioned between the measuring styluses. This type of comparison is referred to as a dynamic comparison because of the handling and transportation of the test piece just prior to the measurement, which, in general, will cause growth or shrinkage due to change of thermal conditions. Attempts are usually made to control these thermal changes within practical limits.

In determining whether or not this type of length comparison would provide the precision necessary for the stability measurements, it was necessary to distinguish errors in comparison caused by lack of control of the dynamic effects from those due to the inherent randomness of

the measuring instrument. The former could possibly be reduced to within acceptable limits, whereas the latter would establish the limit of precision that could be obtained with available instrumentation. An indication of what might be expected in inherent randomness of the mechanical comparator was obtained in an acceptance test conducted when the instrument was purchased. This test measured the relationship between the meter reading and the pressure exerted by the measuring stylus, and avoided the effect from the dynamic changes mentioned as it is independent of length. The results indicated that the inherent randomness of the instrument might possibly be limited to 0·5μin in comparisons of length. If this magnitude was a true indication of the potential instrument performance in length comparisons, it was considered possible to achieve the desired precision provided thermal effects could be controlled to eliminate or nullify effectively the dynamic changes in length of the test specimens.

To eliminate the dynamic changes effectively, the comparison of test specimens would be required under temperature conditions that restricted temperature variation of the specimens to less than 0·02 deg. Fah. This seemed impractical, and an approach to the problem was selected that attempts to nu.lify the dynamic changes in the comparison. It was reasoned that if test specimens to be compared could be treated identically during the comparison and if the specimens responded to thermal variation in an equal manner, dynamic changes of length could be nullified. Therefore the test specimens were divided into groups, all blocks in a group having similar thermal properties. One block of each group was selected as a secondary master. As the secondary masters would in general have different thermal characteristics from the primary master block, it was planned to compare the secondary masters with the primary master by using the interference comparator. The secondary masters would then be used in dynamic comparisons with test specimens of their respective groups using the mechanical comparator. Traditionally the secondary master would be compared with each test specimen in its group. This technique, however, gives special emphasis to the test specimen that was designated as a secondary master and thus violates the requirement of equal handling of all test specimens to nullify dynamic changes occurring during the comparisons. A more appropriate comparison system is one that has been used at the N.B.S. for the comparison of line standards of length with the national standard of length. In this system, the master is handled as one of the test specimens of a group. All possible comparisons of specimens within the group are made to form one inter-comparison test. If the group consists of n specimens, $n(n-1)$ comparisons are made of $n(n-1)/2$ pairs.

A group of n test specimens provides $n(n-1)$ residuals that may be used to evaluate the precision of the results of an inter-comparison test which consists of $n(n-1)$ comparisons.

Conventionally, the sum of the squares of the residuals is determined and the probable error or the standard deviation computed. A multiple of this value is considered to represent a limit to be assigned to the test result. A prediction is made that a certain percentage of repeated tests of the same specimens, using the same measuring technique and equipment, will provide a similar test result within plus or minus this limit. For instance, it is usually accepted that three times the standard deviation will provide a limit within which 99·7 per cent of the test results of a given specimen will be similar. This, in general, is a fallacy as such a condition depends upon the residuals being centred on zero and having a normal or Gaussian distribution.

Therefore, to obtain a better insight of the probable precision of the results of an inter-comparison test and to diagnose the type of measurement error occurring during an inter-comparison test, it was decided to plot frequency distributions of the residuals, i.e. the magnitude of each residual plotted against the number of occurrences. It soon became evident that these distributions could serve as a powerful tool in the development of a satisfactory measuring technique. First, they allowed for a better estimate of the meaning of calculated probable error or standard deviation in regard to the precision of the results of an inter-comparison test. Secondly, they indicated the success achieved in eliminating bias from the comparison procedures and indicated whether this success was temporary or was consistent in repeated inter-comparison tests. Thirdly, they served as a basis for hypothesising the source of error and then served to indicate the effects of test refinements introduced in attempts to eliminate or nullify these sources.

Statistical Control

One of the important features in the development of the measurement method was the use of the results of statistical analyses of the data to guide the evolution of a measuring technique. The measuring technique and the least squares method of data reduction finally employed actually evolved from a series of modifications in procedure and equipment made on the basis of information obtained from the statistical analyses. This statistical approach was then further utilised as a control in monitoring the measuring technique to ensure continuing uniformity.

The statistical analyses of the data resulted in a number of modifications of the measuring technique which are not here reviewed, but an example of how a modification in the actual handling of the sample blocks resulted from information obtained in the statistical analyses might be illustrative. The measurement of dynamic length depends to a very great extent on a symmetry of handling of the samples being measured. The symmetry of handling employed in the stability measurements evolved largely from consideration of the statistical controls. At an early stage in the development of the measuring technique here employed, it had been determined that in making the two comparisons between any pair of blocks it was necessary to physically handle the two blocks together as a pair rather than individually. Thus, in making the comparisons the two blocks involved in any two comparisons would be picked up together with the gloved hand and placed in the comparator. The first and then the second comparison would be made and the blocks then returned as a pair to the storage area. Such a handling procedure, it was believed at the time, resulted in the two blocks in any comparison receiving equal, symmetrical handling. Examination of the residual frequency distributions obtained at this time, however, indicated that the manner in which the blocks were held in the gloved hand has a significant effect on the residuals of the inter-comparison tests. At the time this effect was noticed, the blocks were being held as illustrated in the upper portion of Fig. 7 with one block of the pair exposed to the palm of the glove-insulated hand. The residual distribution obtained in an inter-comparison test in which this handling technique was employed is shown in Fig. 8. It should be noted that the total distribution is plotted at the bottom of the figure, and this distribution is then broken down into the two distributions shown in the upper portion of the figure. The distribution of residuals resulting from first comparisons between each pair of blocks is shown in the central plot, while that obtained from second comparisons is plotted at the top of the figure. It can be seen that the medians of the first and second comparison distributions, shown by the arrows, are not in alignment but are separated by seven ten-millionths of an inch.

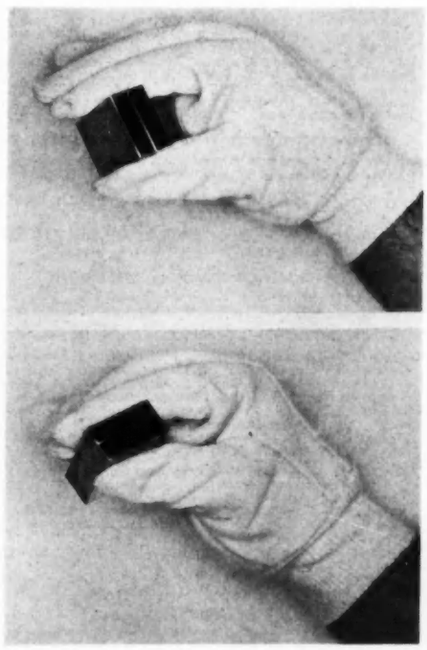


Fig. 7—For inter-comparison tests an asymmetrical thermal effect resulted from the method of holding shown at the top and was eliminated by changing to the method illustrated below

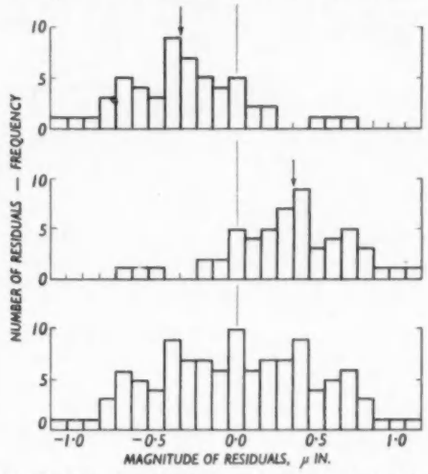


Fig. 8—Frequency distribution of residuals obtained in an inter-comparison test of blocks

The asymmetry suspected as the cause of the split between the medians of the first and second comparison distributions shown was in the handling of the blocks. This suspicion led to changing the manner in which the blocks were held to that shown in the lower view of the illustration. When this handling technique was employed the residual distribution shown in Fig. 9 was obtained. Here, the medians of the first and second comparison distributions are separated by only one ten-millionth of an inch, indicating that the asymmetry has been sharply reduced. This shows how the use of the statistical controls led to a modification of the actual handling techniques employed.

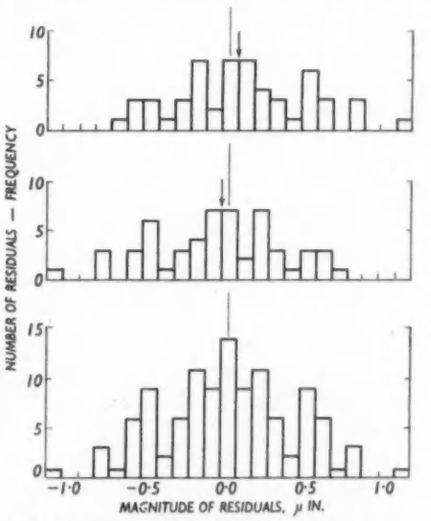


Fig. 9—Frequency distribution obtained from an inter-comparison test with handling modified to correct asymmetrical condition

(*To be continued*)

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Jan. 16.—BRISTOL AND WEST OF ENGLAND BRANCH : Grand Hotel, Bristol, " Modern Developments in Industrial Lighting," A. Pritchard and F. Hounslow, 8 p.m.
Tues., Jan. 17.—NATIONAL EVENT : I.E.E. Lecture Theatre, Savoy Place, London, W.C.2, " Motor Vehicle Electrical Equipment," W. Cooke, 6.30 p.m. ★ OXFORD AND DISTRICTS BRANCH : Employment Exchange, Oxford, " Colour Photography on the Continent," F. E. Garrard, 8 p.m. ★ WEST KENT BRANCH : Rose and Crown Hotel, Tonbridge, " Electrical Problems at an Oil Refinery," W. H. Steel, 7.30 p.m.
Wed., Jan. 18.—WOLVERHAMPTON AND DISTRICT BRANCH : Chamber of Commerce, District Bank Chambers, Lichfield Street, Wolverhampton, " 275kV Severn and Wye Crossing," D. J. Jones, 7.45 p.m.
Fri., Jan. 20.—STOKE AND CREWE BRANCH : Grand Hotel, Hanley, " Semiconductors and Transistors," A. A. Shepherd, 7.30 p.m.

BRITISH INSTITUTE OF RADIO ENGINEERS

Wed., Jan. 18.—COMPUTER GROUP : University College, Gower Street, London, W.C.1, Symposium on " Alpha Numeric Displays," 2 p.m. and 6 p.m. ★ MERSEYSIDE SECTION : Adelphi Hotel, Liverpool, " Microminiaturisation," H. G. Manfield, 7 p.m.

CEMENT AND CONCRETE ASSOCIATION

Mon., Jan. 16.—CAMBRIDGE SECTION : Cambridgeshire Technical College and School of Art, Collier Road, Cambridge, " Concrete Placing and Formwork," A. B. Harman, 7.30 p.m. ★ FOLKESTONE SECTION : Gas Showrooms, Sandgate Road, Folkestone, " Practical Formwork Design and Construction for Concrete," J. G. Richardson, 7.15 p.m.
Wed., Jan. 18.—HALIFAX SECTION : Dept. of Building, Percival Whitley College of Further Education, Hopwood Lane, Halifax, " Concrete Handling on Building Sites," A. W. Richard, 7.15 p.m. ★ TROWBRIDGE SECTION : West Wiltshire and Trowbridge College of Further Education, College Road, Trowbridge, " Essentials of Good Concreting," E. E. H. Bate, 7.15 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Thurs., Jan. 19.—WESTERN REGION : Park Hotel, Cardiff, " Heat Insulation," Martin Edge, and Film " Heat in Harness," 10.30 a.m.

DIESEL ENGINEERS AND USERS ASSOCIATION

Thurs., Jan. 19.—The Institute of Marine Engineers, 76, Mark Lane, London, E.C.3, Symposium on " The Evolution and Trend of Development of Air Cooled Diesel Engines," 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Jan. 17.—LIVERPOOL CENTRE : Electrical Industrial Development Centre, Merseyside and N. Wales Electricity Board, Paradise Street, Liverpool, 1, " Designed Appearance Lighting of Gloucester Cathedral," J. M. Waldram, 6 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Mon., Jan. 16.—EAST ANGLIAN SECTION : Lecture Hall, Public Library, Ipswich, " Origin, Detection and Elimination of Gases in Cast Metals," D. V. Atterton, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Jan. 16.—MERSEYSIDE AND NORTH WESTERN SECTION : Engineers' Club, 17, Albert Square, Manchester, 2, " Safety at Sea," Stewart Hogg, 6.45 p.m. ★ STUDENT LECTURE : Memorial Building, 76, Mark Lane, London, E.C.3, " The Marine Steam Reciprocating Engine," G. Yellowley, 6.30 p.m.
Thurs., Jan. 19.—SOUTHERN JOINT BRANCH : Technical College, Southampton, Joint meeting with the Institution of Naval Architects, " Safety Aspects of Nuclear Propulsion," 7.30 p.m. ★ KINGSTON UPON HULL AND HUMBER AREA SECTION : Royal Station Hotel, Kingston upon Hull, " The Future Doxford Marine Oil Engine," P. Jackson, 7.30 p.m.

INSTITUTE OF METALS

Tues., Jan. 17.—SOUTH WALES LOCAL SECTION : Royal Institution, Swansea, " Metals and Alloys used in the Jewellery and Silverware Industry," Miss D. L. Pile, 7 p.m.
Thurs., Jan. 19.—BIRMINGHAM LOCAL SECTION : College of Technology, Gosta Green, Birmingham, " The Heat-Treatment of Engineering Components," E. Mitchell, 6.30 p.m. ★ SHEFFIELD LOCAL SECTION : Applied Science Building, The University, St. George's Square, Sheffield, " Ductile Fracture," R. W. K. Honeycombe, 7.30 p.m. ★ LIVERPOOL METALLURGICAL SOCIETY : Dept. of Metallurgy, The University, Liverpool, Papers by members of the University of Liverpool Metallurgical Society, and an inspection of the new laboratories, 7 p.m. ★ NORTH EAST METALLURGICAL SOCIETY : Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, " The Effects of Nuclear Radiation on Metals," H. M. Finniston, 7.30 p.m.

INSTITUTE OF NAVIGATION

Fri., Jan. 20.—Royal Geographical Society, 1, Kensington Gore London, S.W.7, " Presentation of Height Information in Aircraft," A. Stratton and K. R. Honick, 5.15 p.m.

INSTITUTE OF PETROLEUM

Wed., Jan. 18.—61, New Cavendish Street, London, W.1, " Queen Elizabeth Islands of Arctic Canada and their Petroleum Prospects," A. Bryce Cameron, 5.30 p.m.

INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

Mon. to Fri., Jan. 16 *to* 20.—Royal Horticultural Society's Old and New Halls, Westminster, London, S.W.1, Annual Exhibition.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Jan. 16.—SCOTTISH CENTRE : Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, " The Design of Commercial Vehicles for Transcontinental Haulage," Mario Persia, 7.30 p.m. ★ MANCHESTER AND DISTRICT CENTRE : Stephenson Room, 3rd Floor, Engineer's Club, Albert Square, Manchester, " Automatic Transmission Control Systems," R. B. Robinson, 7.30 p.m.
Tues., Jan. 17.—EASTERN CENTRE : Davey, Paxman and Co., Ltd., Colchester, " The Design of Commercial Vehicles for Transcontinental Haulage," Mario Persia, 7.30 p.m. ★ NORTH EASTERN CENTRE : Three Tuns Hotel, Durham City, " Air Suspension," V. E. Gough, 7 p.m.
Wed., Jan. 18.—EAST MIDLANDS CENTRE : Mechanics Institute, Nottingham, " The Design of Commercial Vehicles for Transcontinental Haulage," Mario Persia, 7.30 p.m. ★ SOUTH EASTERN CENTRE : Wig and Gown Hotel, Maidstone, Kent, " Problems in Developing the High Speed Diesel Engine," B. W. Millington, 7.30 p.m.
Thurs., Jan. 19.—YORKSHIRE CENTRE : Great Northern Hotel, Wellington Street, Leeds, 1, " The Work of the Motor Industry Research Association," J. G. Giles, 7.30 p.m. ★ METROPOLITAN AREA : Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, " The Design of Commercial Vehicles for Transcontinental Haulage," Mario Persia, 6.30 p.m.
Fri., Jan. 20.—SOUTH WALES CENTRE : South Wales Institute of Engineers, Park Place, Cardiff, " The Design of Commercial Vehicles for Transcontinental Haulage," Mario Persia, 7.15 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., Jan. 18.—NORTH WESTERN BRANCH : Lecture Theatre A, Houldsworth School of Applied Science, Reservoir Street, Leeds, 2, " Chemical Process Design," J. M. Coulson, 6.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Jan. 17.—Great George Street, London, S.W.1, " A Civil Engineer and Town Planning," S. G. Wardley, 5.30 p.m.
Wed., Jan. 18.—VERNON-HARCOURT LECTURE : Great George Street, London, S.W.1, " Irrigation Projects for Arid Areas," A. M. R. Montagu, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Jan. 13.—NORTH SCOTLAND SUB-CENTRE : Robert Gordon's Technical College, Aberdeen, " Discrimination between H.R.C. Fuses," E. Jacks, 7.30 p.m.
Mon., Jan. 16.—NORTH EASTERN MEASUREMENT AND ELECTRONICS GROUP : Rutherford College of Technology, Northumberland Road, Newcastle upon Tyne, " Precision Measurement," G. H. Rayner and A. Felton ; " Improvements in the Precision Measurement of Capacitance," G. H. Rayner and L. H. Ford ; " The Design of an Audio-Frequency Amplifier for High-Precision Voltage Measurement," S. Harkness and F. J. Wijkins ; " The Design and Performance of High-Precision Audio-Frequency Current Transformers," J. J. Hill and A. P. Miller, and " Techniques for the Calibration of Standard Current Transformers up to 20 kc/s," J. J. Hill, 6.15 p.m. ★ SCOTTISH ELECTRONICS AND MEASUREMENT GROUP : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, " Applications of Microwaves," A. L. Cullen, 6 p.m. ★ SOUTH MIDLAND CENTRE : B.B.C. Training School, Wood Norton, Near Evesham, " Magnetic Recording of T.V. Programmes," H. E. Farrow, 7.30 p.m. ★ NORTH STAFFORDSHIRE SUB-CENTRE : Technical College, Stafford, " Some Considerations in the Application of Power Rectifiers and Convertors," J. P. McBreen, 7 p.m. ★ WESTERN SUPPLY GROUP : Demonstration Theatre, Electricity House, Colston Avenue, Bristol, 1, " The Shielding of Overhead Lines Against Lightning," J. H. Gridley, 6 p.m. ★ READING DISTRICT BRANCH : George Hotel, King Street, Reading, Open Forum, 7.15 p.m.
Tues., Jan. 17.—NORTH MIDLAND UTILISATION GROUP : Leeds and County Conservative Club, South Parade, Leeds, 1, " The Characteristics and Protection of Semiconductor Rectifiers," D. B. Corbyn and N. L. Potter, 6.30 p.m. ★ NORTH-WESTERN MEASUREMENT AND CONTROL GROUP : Engineers' Club, Albert Square, Manchester, " A Universal Non-Linear Filter, Predictor and Simulator, which Optimises itself by a Learning Process," D. Gabor, W. P. L. Wilby and R. Woodcock, 6.15 p.m. ★ SCOTTISH ELECTRONICS AND MEASUREMENT GROUP : Carlton Hotel, North Bridge, Edinburgh, " Applications of Microwaves," A. L. Cullen, 7 p.m. ★ SOUTHERN CENTRE : Technical College, Farnborough, " Modern Ferromagnetic Materials," F. Brailsford, 6.15 p.m.
Wed., Jan. 18.—SUPPLY SECTION : Savoy Place, London, W.C.2, " A General Method of Digital Network Analysis particularly Suitable for Use with Low-Speed Computers," M. N. John ; and " Digital Computers in Power System Analysis," P. P. Gupta and M. W. Humphrey Davies, 5.30 p.m. ★ LONDON GRADUATE AND STUDENT SECTION : Visit to The Mullard Radio Valve Company, Ltd., Mitcham, 2 p.m. ★ SHEFFIELD SUB-CENTRE : Memorial Hall, City Hall, Sheffield, Third Hunter Memorial Lecture, " The Application of Electronics to the Electricity Supply Industry," J. S. Forrest, 6.30 p.m. ★ SOUTH-WEST SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Sub-Centre Chairman's Address, W. L. Kidd, 6 p.m. ★ RUGBY SUB-CENTRE : College of Technology and Arts, Rugby, " Field Suppression of Turbo-Alternators," J. R. Hill, A. Hunt, W. J. Joyce and D. H. Tompsett, 6.30 p.m. ★ SOUTH-WESTERN SUB-CENTRE : Plymouth " B " Generating Station, Prince Rock, Plymouth, " Discrimination between H.R.C. Fuses," E. Jacks, 3 p.m.
Thurs., Jan. 19.—NORTH MIDLAND CENTRE : Lecture Theatre, Y.E.B. Offices, Ferensway, Hull, Repeat of Chairman's Address, F. W. Fletcher, 6.30 p.m. ★ IRISH BRANCH : Physical Laboratory, Trinity College, Dublin, " Magnetism or Electricity (the Hen or the Egg)," J. V. Byrne, 6 p.m.
Fri., Jan. 20.—EDUCATION DISCUSSION CIRCLE : Savoy Place, London, W.C.2, Discussion on " Management Studies for Junior Engineers," opened by G. S. C. Lucas, 6 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Wed., Jan. 18.—YORKSHIRE BRANCH : Midland Hotel, Bradford, " Lighting in Home and Industry," J. W. Howell, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Jan. 17.—39, Elmbank Crescent, Glasgow, " Some Problems in Shipbreaking," M. Wilkinson, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Wed., Jan. 18.—NORTHERN BRANCH : Town Hall, Penrith, " Heavy Haulage," E. G. Milne, 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Tues., Jan. 17.—Lecture Hall, Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, " Spectrographic Analysis of Crankcase Lubricating Oils as a Guide to Preventive Maintenance of Locomotive Diesel Engines," G. M. Barrett, and " Control of Quality of Crankcase Lubricating Oils of Locomotive Diesel Engines in Service," S. Bairstow, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Today, Jan. 13.—SCOTTISH BRANCH : Robert Gordon's Technical College, Aberdeen, " Corrosion Fatigue," A. W. Scott, 7.30 p.m.
Mon., Jan. 16.—DERBY A.D. CENTRE : Midland Hotel, Derby ; " The Non-destructive Testing of Aero-engine Components," W. G. Cook, 7.30 p.m. ★ E. BRANCH GRADUATES' SECTION : Town Hall, Luton ; " Development of the Spectre Rocket Engine," W. Neat, 7.30 p.m.
Tues., Jan. 17.—N.W., A.D., CENTRE : Warrington Masonic Hall, Warrington, " Automobile Transmission," Dr. Tait, 7.15 p.m.
Wed., Jan. 18.—N.E., A.D., CENTRE : Chemistry Lecture Theatre, The University, Leeds, " Something New in Diesel Fuel Systems," S. B. Hartshorne, 7.30 p.m. ★ EASTERN BRANCH GRADUATES' SECTION : Visit to Slough Trading Estate, Power Station, 7.30 p.m. ★ E. MIDLANDS BRANCH GRADUATES' SECTION : Technical College, Eastfield Road, Peterborough Film Show, 7.15 p.m.
Thurs., Jan. 19—EASTERN BRANCH : The Good Companions Hotel, Slough, " Some Design Problems in Modern Railway Signalling," O. S. Nock, 7.30 p.m. ★ MIDLAND BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, " Do Managers Manage? " A Norman Giles, 6 p.m. ★ SOUTHERN BRANCH : The Royal Beach Hotel, Southsea, " Some 'Trivial' Examples of Research in Mechanical Engineering," W. J. Evans, 7 p.m. ★ N. IRELAND GRADUATES' SECTION : Georgian Rooms, May Street, Belfast, Annual General Meeting, Film Show, 7 p.m. ★ YORKSHIRE GRADUATE SECTION : Hotel Metropole, Leeds, " Labour Management," K. Wainwright, 6.30 p.m.
Fri., Jan. 20.—N.E. BRANCH GRADUATES' SECTION : Rutherford College, Newcastle, " Problems in the Design and Operation of Ejectors," M. O. Engel, 6.30 p.m.
Sat., Jan. 21.—E. MIDLANDS GRADUATES' SECTION : Visit to Derby Evening Telegraph, Northcliffe House, Derby, 10.45 a.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., Jan 19.—Geological Society, Burlington House, Piccadilly, London, W.1, " Nchanga Mine, Northern Rhodesia," M. W. Rushton, 5 p.m.

INSTITUTION OF PLANT ENGINEERS

Tues., Jan. 17.—New Lecture Theatre, Royal Aeronautical Society, 4, Hamilton Place, London, W.1, " Hovercraft," R. A. Shaw, 7 p.m.
Wed., Jan. 18.—KENT BRANCH : King's Head Hotel, High Street, Rochester, " Photography in Industry," N. E. Sherlock, 7 p.m.
Thurs., Jan. 19.—BLACKBURN BRANCH : Castle Hotel, Blackburn, " Industrial Heating and Ventilating," S. P. Fildes, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Tues., Jan. 17.—LONDON GRADUATE SECTION : 10, Chesterfield Street, Mayfair, London, W.1, " Modern Welding Techniques," W. H. Holland, and film, " New Welding Techniques," 7.15 p.m.
Wed., Jan. 18.—MIDLANDS REGION : James Watt Memorial Institute, Great Charles Street, Birmingham, " Design and Production Engineering of Materials Utilization," B. H. Dyson, 7 p.m. ★ WOLVERHAMPTON GRADUATE SECTION : Wolverhampton and Staffs. College of Technology, Wulfruna Street, Wolverhampton, " The Application of Electronic Computers to Production Control," B. L. J. Hart, 7 p.m. ★ NORTH MIDLANDS REGION : Conference Room, Peterscourt, Peterborough, " Measurement of Time," H. M. Smith, 7.30 p.m.
Thurs., Jan. 19.—SOUTHERN REGION : Blue Room, Reading Co-operative Society Ltd., Cheapside, Reading, " The Art of Delegation," A. C. Leyton, 7.30 p.m. ★ SOUTHERN REGION : Polygon Hotel, Southampton, " Production Control," H. Horne, 7.15 p.m.

INSTITUTION OF PUBLIC HEALTH ENGINEERS

Thurs., Jan. 19.—Caxton Hall, London, S.W.1, " Some Applications of Hydraulic Research in Civil Engineering," S. T. Bonnington, 6 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Jan. 17.—LANCASHIRE AND CHESHIRE BRANCH : College of Science and Technology, Manchester, " Vibration Problems in Relation to Foundation Design and Construction," J. H. A. Crockett, 6.30 p.m.
Wed., Jan. 18.—YORKSHIRE BRANCH : Metropole Hotel, King Street, Leeds, " Research for the Concrete Industry," A. R. Collins, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

Today, Jan. 13.—Pepys House, 14, Rochester Row, London, S.W.1, " Xerography and Allied Subjects," W. C. C. Ball, 7 p.m.
Fri., Jan. 20.—Pepys House, 14, Rochester Row, London, S.W.1, " Radio Investigations of the Solar Atmosphere," J. Heywood, 7 p.m.

REINFORCED CONCRETE ASSOCIATION

Wed., Jan. 18.—11, Upper Belgrave Street, London, S.W.1, " Structural Analysis and Digital Computers," J. Munro, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

To-day, Jan., 13.—ROTORCRAFT SECTION : Lecture Theatre, 4, Hamilton Place, London, W.1, " Certification of Civil Transport Rotorcraft with particular reference to Multi-Engines," H. E. Le Sueur, 6 p.m.
Wed., Jan. 18.—AGRICULTURAL AVIATION GROUP : Lecture Theatre, 4, Hamilton Place, London, W.1, " Locust Control from the Air," R. C. Rainey, 7 p.m.
Thurs., Jan. 19.—SOUTHAMPTON BRANCH : Lecture Theatre, The University, Southampton, Main Lecture, " Trends in Aircraft Propulsion," H. Pearson, 8 p.m.
Fri., Jan. 20.—MAN POWERED AIRCRAFT GROUP : Lecture Theatre, 4, Hamilton Place, London, W.1, " Gliding and Man Powered Flight," Lorne Welch, 7 p.m.

ROYAL STATISTICAL SOCIETY

Wed., Jan. 18.—London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1, " Operational Research," K. D. Tocher, 5.15 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Wed., Jan. 18.—CORROSION GROUP : 14, Belgrave Square, London, S.W.1, " Metallic Diffusion Coatings," R. L. Samuel, 6 p.m.
Thurs., Jan. 19.—ROAD AND BUILDING MATERIALS GROUP : 14, Belgrave Square, London, S.W.1, " Problems Associated with Research on Aggregates," J. P. R. Jordan, 6 p.m.

SOCIETY OF ENVIRONMENTAL ENGINEERS

Thurs., Jan. 19.—Imperial College, Exhibition Road, London, S.W.7, " The Development of Accelerated Climatic Tests," K. W. Jones, and Discussion, 6 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., Jan. 20.—Elmbank Crescent, Glasgow, " The Relative Merits of Different Steelmaking Processes," T. F. Pearson, 6.45 p.m.

Advanced Engineering Courses

Liquid Fuels, Their Properties and Utilisation. BOROUGH POLYTECHNIC, Borough Road, London, S.E.1. A course of six lectures, Tuesday evenings, commencing January 31 at 7 p.m. The course will provide a survey of present-day knowledge and will cover recent developments in both European and American practice. Fee 10s.

Developments Affecting the Control of Quality in Machine Tool Operations. BOROUGH POLYTECHNIC, Borough Road, London, S.E.1. A course of six lectures to be held on Wednesday evenings, commencing January 25 at 7 p.m. A survey of modern practice in the control of quality of the machine product with regard to dimensional accuracy, geometrical form and surface finish. The course is intended for production executives, mechanical engineers, electronic engineers and inspectors concerned with quality control. Fee 10s.

Experimental Stress Analysis. BOROUGH POLYTECHNIC, Borough Road, London, S.E.1. A course of seven lectures to be given on Thursday evenings, commencing January 26. A survey of the principles and techniques employed in the experimental determination of stresses in engineering structures and components. The course covers mechanical gauges, photo-elastic methods for two dimensional and three dimensional analysis, surface film techniques, electrical strain gauges, replica method and pneumatic extensometry. The course is intended for qualified engineers and for students in their final years. Fee £1.